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SMUT RESISTANCE IN AN ALLIUM SPECIES HYBRID[1]

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INTRODUCTION

Smut (*Urocystis cepulae* Frost) of onion (*Allium cepa* L.) is widely distributed and is of considerable economic importance in the northern onion-growing sections of the United States. Only in the seedling stage is the host susceptible to attack, since all infection takes place through the cotyledon, which was found by Anderson (*1*)[3] to be susceptible until about the time the first leaf emerges. Walker and Jones (*11*) found that the infection takes place at soil temperatures between 10° and 27° C. and that the disease develops better at soil and air temperatures of 15° and 20° than at temperatures above 20°. Walker and Wellman (*12*) later showed that the optimum temperature for germination of chlamydospores and hyphal fragments of the pathogen was between 13° and 20°, while the mycelium grew best at 18°.

Onion smut in commercial fields is controlled by applying formaldehyde in the row at the time of seeding. Nevertheless, the development of resistant varieties would be of value, since their use would eliminate considerable labor and expense. Anderson (*2*) tested 54 varieties of cultivated onions and since none showed any marked resistance to the disease, it appears probable that all commercial varieties of *Allium cepa* are susceptible to invasion by the smut organism. However, in a test of 39 other species of *Allium*, 8 appeared immune. Seed obtained from Germany under the name "Winterbeck Zwiebel" proved highly resistant, since only 2 or 3 percent of the seedlings developed smut in the cotyledons and none was seen in any later stage. Anderson's description of this variety suggests that it belongs to *A. fistulosum* L. Felix (*6*) also found that the Nebuka type of *A. fistulosum* was highly resistant to smut. Evans (*4*) traced the host-parasite relation during the growth of the cotyledon of *A. cepa* and found the development of an increasing intracellular protoplasmic resistance as the cotyledon approached maturity. In a later study with *A. fistulosum* (*5*) he found the same defense mechanism more highly developed in the lower half of the cotyledon. This accounted for the low incidence of infection below the point of emergence of the first leaf. When infection occurred above this point systemic invasion of the true leaves was precluded.

Allium cepa and *A. fistulosum* cross fairly readily, and interspecific hybrids have been obtained by Emsweller and Jones (*3*), Levan (*8*, *9*), and Maeda (*10*). Unfortunately these hybrids have been highly self-

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[3] Italic numbers in parentheses refer to Literature Cited, p. 7.

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sterile, but recently Jones and Clarke (7) obtained a fertile amphidiploid from a cross between these two species. *A. fistulosum* is then a source of smut resistance that may be incorporated into commercial varieties of onions. The behavior of these hybrids and their backcross generations to *A. cepa* in relation to smut resistance is presented in this paper.

MATERIALS AND METHODS

The crossing was done in the greenhouses of the Bureau of Plant Industry Station, Beltsville, Md., and the testing for resistance was handled in the greenhouses of the Wisconsin Agricultural Experiment Station, Madison, Wis. In these tests Nebuka was the only type of *Allium fistulosum* used. Commercial varieties of *A. cepa* were obtained from various seed firms. The amphidiploid was the one reported by Jones and Clarke (7). It was obtained from a cross between the variety Australian Brown of *A. cepa* and Nebuka.

For the resistance test, thoroughly infested soil was obtained from a field in southeastern Wisconsin. The infestation was enhanced by the incorporation of spores from infected plants collected in the same area. Infested soil 3 inches deep was placed in greenhouse flats 20 by 14 by 3½ inches. Seed was sown in furrows three-fourths inch deep and 4 inches apart and covered; the usual greenhouse watering followed. The air temperature averaged about 22° C. and the soil temperature slightly below 20°.

Seedlings were grown until the cotyledon was fully developed and the first leaf about half grown. They were then removed carefully, all soil was washed off, and an examination was made for the presence and location of lesions. The diseased plants were placed in one of three classes, depending upon the location of the lesion, as follows:

(1) Lesion on cotyledon only above the point of emergence of the first leaf (crotch). Plants so affected practically always continue healthy.
(2) Lesion on cotyledon at or very near the crotch. Such plants may or may not escape systemic infection.
(3) Lesions on cotyledon below the crotch. Such plants usually become infected more or less systemically.

EXPERIMENTAL RESULTS

In 1936–37, 1,844 plants of *Allium fistulosum* were tested for smut resistance, and only 111, or 6.0 percent, developed lesions. All the lesions were above the crotch where they did little injury, and the attacked seedlings were able to survive. Plants of 3 varieties of *A. cepa* grown as controls were affected as follows: Of 88 plants of Ebenezer, 86.4 percent were diseased; of 108 plants of Sweet Spanish, 73.2 percent; and of 92 plants of Early Grano, 68.5 percent. The difference in amount of infection is actually more marked than these figures indicate, because, as a rule, infected seedlings of *A. cepa* develop a majority of the lesions below the crotch. In later tests plants were classified according to the position of the smut lesion in relation to the crotch of the cotyledon and first leaf.

No tests were made in 1937–38, but in 1938–39, as shown in table 1, Nebuka again proved highly resistant. Only 0.9 percent of the plants of this variety developed smut lesions below the crotch, in contrast with 74.9 percent of seven varieties of *Allium cepa*. The hybrids between *A. cepa* and Nebuka also showed considerable resistance, as

only 13.7 percent of these plants developed lesions below the crotch. The percentage of infected plants in the hybrids was higher than in Nebuka but much lower than in the commercial varieties of *A. cepa*, indicating that the factor or factors for smut resistance are incompletely dominant.

Since the F_1 diploid plants were self-sterile it was not possible to obtain an F_2 population. The hybrids when used as the male parent in backcrosses to *Allium cepa* gave some seed. Unfortunately, these backcross populations were too small to justify drawing definite conclusions regarding the mode of inheritance of smut resistance, but it does seem that the percentage of plants which developed lesions below the crotch was much higher than in the F_1 populations. Seedlings that survived this test were retained for further breeding studies.

Similar results were obtained in 1939–40. These data are summarized in table 2. The percentages of seedlings which developed smut lesions below the crotch were 0.6, 61.2, and 8.7 for *Allium fistulosum*, *A. cepa*, and their F_1 hybrids, respectively. The first and second

TABLE 1.—*Results of testing commercial onion varieties, Nebuka, F_1 hybrid progenies, and first and second backcrosses to onion for resistance to smut in the greenhouse at Madison, Wis., 1938–39*

Variety or pedigree	Plants tested	Plants not smutted	Plants smutted			Tested plants smutted below crotch
			Total	With lesion in indicated position		
				At or above crotch	Below crotch	
Allium cepa (commercial varieties):	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
Australian Brown	73	11	62	15	47	64.4
Crystal Wax	310	13	297	56	241	77.8
Southport Red Globe	38	11	27	13	14	36.8
Southport Yellow Globe	29	0	29	0	29	100.0
White Portugal	82	8	74	15	59	72.0
Yellow Bermuda	17	0	17	2	15	88.2
Yellow Globe Danvers	24	0	24	0	24	100.0
Total	573	43	530	101	429	74.9
A. fistulosum (Nebuka)	215	196	19	17	2	0.9
F_1 (*A. cepa* × *A. fistulosum*):						
Australian Brown × Nebuka	501	136	365	321	44	8.8
Ebenezer × Nebuka	220	92	128	101	27	12.3
Red Creole × Nebuka	24	8	16	14	2	8.3
Yellow Globe Danvers × Nebuka	50	14	36	31	5	10.0
Southport Red Globe × Nebuka	72	22	50	39	11	15.3
Sweet Spanish × Nebuka	23	18	5	5	0	0.0
White Portugal × Nebuka	220	54	166	103	63	28.6
Total	1,110	344	766	614	152	13.7
First backcross to *A. cepa*:						
Australian Brown × F_1	2	0	2	0	2	100.0
Early Grano × F_1	7	1	6	0	6	85.7
Southport Yellow Globe × F_1	4	0	4	0	4	100.0
Total	13	1	12	0	12	92.3
Second backcross to *A. cepa*:						
Early Grano × first backcross	49	11	38	25	13	26.5
Southport Yellow Globe × first backcross	21	0	21	3	18	85.7
White Portugal × first backcross	15	0	15	1	14	93.3
Total	85	11	74	29	45	52.9

backcross generations to *A. cepa* were as badly infected with smut as the original commercial varieties used in the crosses. Only 20 percent of the seedlings of the third backcross generation became infected below the crotch, but since only 25 seedlings were tested not much significance can be attached to this result.

TABLE 2.—*Results of testing commercial onion varieties, Nebuka, F_1 hybrid progenies, and first, second, and third backcrosses to onion for resistance to smut in the greenhouse at Madison, Wis., 1939–40*

Variety or pedigree	Plants tested	Plants not smutted	Plants smutted			Tested plants smutted below crotch
			Total	With lesion in indicated position		
				At or above crotch	Below crotch	
Allium cepa (commercial varieties):	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
Brigham Yellow Globe	33	1	32	17	15	45.5
Crystal Wax	20	1	19	11	8	40.0
Early Yellow Globe	235	10	225	100	125	53.2
Mountain Danvers	159	15	144	58	86	54.1
Red Creole	57	1	56	12	44	77.2
Yellow Globe Danvers	145	8	137	18	119	82.1
Total	649	36	613	216	397	61.2
A. fistulosum (Nebuka)	1,088	936	152	146	6	0.6
F_1 (*A. cepa* × *A. fistulosum*):						
Crystal Wax × Nebuka	57	21	36	33	3	5.3
Red Creole × Nebuka	99	42	57	49	8	8.1
Mountain Danvers × Nebuka	39	8	31	25	6	15.4
Total	195	71	124	107	17	8.7
First backcross to *A. cepa*:						
Early Yellow Globe × F_1	200	10	190	59	131	65.5
White Portugal × F_1	12	0	12	4	8	66.7
Total	212	10	202	63	139	65.6
Second backcross to *A. cepa*:						
Brigham Yellow Globe × first backcross	38	3	35	20	15	39.5
Early Yellow Globe × first backcross	75	3	72	32	40	53.3
Southport White Globe × first backcross	16	0	16	3	13	81.2
Yellow Bermuda × first backcross	180	9	171	37	134	74.4
Total	309	15	294	92	202	65.4
Third backcross to *A. cepa*:						
Brigham Yellow Globe × second backcross	17	1	16	13	3	17.6
Early Yellow Globe × second backcross	8	0	8	6	2	25.0
Total	25	1	24	19	5	20.0

In the 1941–42 trials, Nebuka again proved highly resistant, only 0.5 percent of the plants developing lesions below the crotch as compared with 81.3 percent of the Yellow Globe Danvers and 82.1 percent of the backcross populations (table 3). Again, the backcross populations appeared as susceptible as the susceptible parent. A statistical analysis of the results summarized in table 3 failed to establish any significant differences between the various backcross populations in their degree of resistance to the smut organism.

In 1941 two populations of the amphidiploid were tested. One was a P_2 population obtained by selfing the original amphidiploid and the other a mixture of P_3 progenies from these P_2 plants. The data

are summarized in table 4. None of the Nebuka plants smutted below the crotch, while 98.8 percent of the Yellow Globe Danvers became infected at an early stage. The amphidiploid was intermediate in its reaction, 38.0 percent of the P_2 and 59.1 percent of the P_3 population becoming infected below the crotch. While this difference between the P_2 and P_3 populations is highly significant, as measured by the chi-square goodness-of-fit test, it may be the result of variation in the quantity of the smut organism present rather than of a genetic difference between the P_2 and P_3 plants.

TABLE 3.—*Results of testing a commercial variety of onion, Nebuka, and backcrosses to onion for resistance to smut in the greenhouse at Madison, Wis., 1941–42*

Variety or pedigree	Plants tested	Plants not smutted	Plants smutted			Tested plants smutted below crotch
			Total	With lesion in indicated position		
				At or above crotch	Below crotch	
	Number	*Number*	*Number*	*Number*	*Number*	*Percent*
Allium cepa (Yellow Globe Danvers)	342	51	291	13	278	81.3
A. fistulosum (Nebuka)	189	181	8	7	1	.5
Backcross to *A. cepa:*						
Early Yellow Globe × (Brigham Yellow Globe×Nebuka)	71	9	62	3	59	83.1
Do	20	0	20	2	18	90.0
Do	220	32	188	17	171	77.7
Do	192	51	141	10	131	68.2
Brigham Yellow Globe×(Yellow Bermuda×Nebuka)	22	3	19	0	19	86.4
Do	111	30	81	4	77	69.4
Do	110	0	110	0	110	100.0
Do	131	16	115	10	105	80.2
Brigham Yellow Globe×(White Portugal×Nebuka)	26	3	23	3	20	76.9
Do	167	5	162	4	158	94.6
Do	107	5	102	4	98	91.6
Total for backcrosses	1,177	154	1,023	57	966	82.1

TABLE 4.—*Results of testing a commercial variety of onion, Nebuka, and P_2 and P_3 amphidiploid progenies for resistance to smut in the greenhouse at Madison, Wis., 1941*

Variety or amphidiploid population	Plants tested	Plants not smutted	Plants smutted			Tested plants smutted below crotch
			Total	With lesion in indicated position		
				At or above crotch	Below crotch	
	Number	*Number*	*Number*	*Number*	*Number*	*Percent*
Nebuka	479	468	11	11	0	0
Yellow Globe Danvers	166	0	[1] 166	2	57	[1] 98.8
Amphidiploid P_2 population	237	105	132	42	90	38.0
Amphidiploid P_3 population	734	77	657	223	434	59.1

[1] The position of the lesion on 107 of these plants was indefinite, largely because they were infected so severely that the first leaf stage was not reached. These plants were included with those smutted below the crotch in calculating the percentage smutted below the crotch.

The partial resistance of the amphidiploid was confirmed in a later test, summarized in table 5. Progenies from 15 P_2 amphidiploid plants were grown and the percentage of seedlings that became infected with smut below the crotch ranged from 6.5 to 26.1 percent, the mean infection being 17.2 percent. A statistical analysis showed that the differences in percentage of infection between these P_3 amphidiploid populations were not significant. From 60.0 to 76.9 percent of the seedlings of commercial varieties of onions were smutted below the crotch of the first leaf, while only 1.0 percent of the Nebuka seedlings were infected. The amphidiploid plants, therefore, were definitely intermediate in their reaction to smut infection.

TABLE 5.—*Results of onion smut resistance trials of Nebuka, commercial varieties of onion, and P_1 and P_3 amphidiploid populations, Madison, Wis., 1941–42*

Variety or amphidiploid number	Plants tested	Plants not smutted	Plants smutted			Tested plants smutted below crotch
			Total	With lesion in indicated position		
				At or above crotch	Below crotch	
	Number	*Number*	*Number*	*Number*	*Number*	*Percent*
White Portugal	168	17	151	26	125	74.4
Yellow Globe Danvers	70	15	55	13	42	60.0
Utah Sweet Spanish	39	4	35	5	30	76.9
Total	277	36	241	44	197	71.1
Nebuka	98	92	6	5	1	1.0
Amphidiploid No. 15	124	68	56	29	27	21.8
Amphidiploid No. 26	130	95	35	18	17	13.1
Amphidiploid No. 49	162	98	64	30	34	21.0
Amphidiploid No. 56	175	109	66	31	35	20.0
Amphidiploid No. 83	185	107	78	37	41	22.2
Amphidiploid No. 141	176	105	71	25	46	26.1
Amphidiploid No. 151	151	108	43	31	12	7.9
Amphidiploid No. 170	166	89	77	43	34	20.5
Amphidiploid No. 182	168	142	26	15	11	6.5
Amphidiploid No. 198	176	134	42	20	22	12.5
Amphidiploid No. 199	173	131	42	23	19	11.0
Amphidiploid No. 230	145	112	33	18	15	10.3
Amphidiploid No. 238	123	55	68	37	31	25.2
Amphidiploid No. 300	159	89	70	40	30	18.9
Amphidiploid No. 313	167	96	71	36	35	21.0
Total	2,380	1,538	842	433	409	17.2

DISCUSSION

It would seem that the most practical breeding procedure to follow in attempting to combine the smut resistance of the Nebuka parent with the desirable qualities of commercial varieties of *Allium cepa* is to make repeated backcrosses of the hybrids to the *A. cepa* parent. Since the F_1 plants show some resistance to the smut organism, indicating that smut resistance is partially dominant, it should be possible by testing the seedlings to select smut-resistant plants from second, third, and later backcross generations, although the results thus far have not proved very encouraging. Unfortunately, the F_1 and first backcross generations are self-sterile, but it is hoped that later backcross generations will show sufficient fertility to permit

selfing, in order that homozygous fertile smut-resistant lines may be developed.

Since this backcrossing method has not thus far been very successful, it may be that the utilization of the fertile amphidiploid will prove to be more satisfactory. This amphidiploid has been successfully backcrossed to *Allium cepa*, to *A. fistulosum*, and to the diploid hybrid between these two species. Seed has been obtained from these triploid hybrids, but it is not possible to report on their reaction to smut until they have been tested for smut resistance.

Recently M. G. Toole and A. E. Clarke,[4] of this Division, have obtained tetraploid plants of both *Allium fistulosum* and *A. cepa* by treating germinating seeds with colchicine. These plants have been selfed successfully; also crosses have been made between them and the fertile amphidiploid.

Another method of attack which is being followed is backcrossing the diploid hybrid to *Allium cepa* and then getting fertility by doubling the chromosomes with colchicine. Work is being continued with this material in an effort to obtain smut-resistant commercial types.

SUMMARY

Seedlings of the Nebuka type of *Allium fistulosum* are highly resistant to the smut disease of onion, caused by the fungus *Urocystis cepulae*, while the commercial varieties of *A. cepa* are extremely susceptible. F_1 hybrids between these two species show considerably more resistance than the susceptible but not as much as the resistant parent. These hybrids are self-sterile, so that no F_2 populations were obtained. When backcrossed to *A. cepa* the backcross populations proved highly susceptible, but seedlings that survived the smut test have been retained for further breeding studies.

A fertile amphidiploid obtained by crossing these two species has shown considerable resistance.

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EFFECTS OF SOIL TREATMENTS ON THE GROWTH OF THE HIGHBUSH BLUEBERRY [1]

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INTRODUCTION

The cultivation of the blueberry is one of the newer fruit industries in North America. The blueberry plant is known to be profoundly influenced by soil, yet data are very limited on the influence of nutrient supply and fertilizer treatments on either vegetative growth or productivity. It is believed that the results of the study of various soil treatments reported in this paper may be useful to those engaged in the culture of this plant.

REVIEW OF LITERATURE

Coville, [3] who was the pioneer in the domestication and improvement of the highbush blueberry (*Vaccinium corymbosum* L.), showed that one of its principal requirements for satisfactory growth and productivity is a rather sharply acid soil. Data indicating, at least approximately, the pH tolerance of the plant were first reported in 1934 by Johnston.[4] According to Johnston there is a fairly wide range of pH within which blueberry plants will grow well. The optimum pH value was found to be approximately 4.4. The plants used in his experiments grew fairly well on a soil as acid as pH 3.4, which led to the belief that few Michigan soils are so highly acid that they are unsuitable for blueberry culture. However, poor growth, or even failure of plants, has been noted on certain extremely acid soils.

Beckwith and Coville,[5] reporting on the results of a blueberry fertilizer experiment in New Jersey, state: "An application of nitrate of soda at the rate of 250 pounds to the acre for two years did not materially increase the yield." However, they found that an application of a mixture of 250 pounds of nitrate of soda, 750 pounds of acid phosphate, and 250 pounds of 28 percent potash to the acre doubled the yield. They further state: "A mixture of 170 pounds of nitrate of soda, 230 pounds of dried blood, 340 pounds of steamed bone, 340 pounds of phosphate rock, and 170 pounds of 28 percent potash to the acre nearly tripled the yield." Beckwith and Coville draw the following conclusion: "The results indicate that fertilizer, if carefully mixed and used, will greatly increase the yield of blueberries."

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Concerning the application of a nitrogen fertilizer on Saugatuck sand in Michigan, Johnston[6] states: "Sulphate of ammonia gave poor results, the plants producing somewhat less fruit than those receiving no fertilizer." Nitrate of soda failed to show any greater response than sulphate of ammonia. "Very good results followed the use of 335 pounds of superphosphate per acre. Good results also were obtained from the use of a 5–10–12 fertilizer at the rate of 335 pounds per acre." Johnston also found that doubling the amount of superphosphate (to 670 pounds per acre) gave an increased yield of 38.2 percent the first year and 23.4 percent the second year. These same plots, however, had received three previous applications of superphosphate at the rate of 335 pounds per acre. Evidence of the value of potash alone is lacking in Johnston's work, but he is of the opinion that it is beneficial because his largest yields were obtained from complete fertilizer plots. He concludes by saying: "* * * it is evident that another factor besides phosphorus was responsible for the gain. Since nitrogen alone was clearly not beneficial, potash can be considered as being responsible." Johnston also stated that the size of the fruit was larger on the complete fertilizer plots than on those that received superphosphate alone.

Doehlert and Shive,[7] in a study of the blueberry grown in sand cultural solutions, reported that the solutions giving the best results, both in plant growth and production of berries, were characterized by low monopotassium phosphate and high nitrogen content. They state: "The high-yielding group is also characterized by treatments in which high proportions of calcium nitrate and, generally, low proportions of ammonium sulfate predominate."

The results of Doehlert's and Shive's sand culture experiments were in close accord with the findings of Beckwith and Doehlert,[8] who demonstrated that the greatest yield of fruit was obtained with the use of nitrate of soda alone, though admitting that the benefit of a complete fertilizer may have been obscured by excessive applications of rock phosphate.

Doehlert and Shive[9] also found that the blueberry's need for magnesium was slight, 0.5 p. p. m., and increasing applications above that amount had a retarding effect upon growth.

Chandler and Mason,[10] referring to the upland sandy soils of Maine, state that increased growth and better color of foliage were obtained on all plots that received nitrogen, but the plants on the plots that received only phosphorus and potash were not much better than those on the untreated plots. Increased yields of fruit were obtained for three seasons from the plots that received nitrogen and for two seasons from those that received phosphorus and potash. The complete fertilizer gave an increase of 128.6 percent over the check for the first season, 85 percent for the second, and 217.6 percent for the third season. In summarizing their work, they state that fertilizers carrying nitrogen stimulated growth, increased the number of fruit buds per stem, and gave greater yields as compared with untreated plots.

[6] See footnote 4, p. 9.

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[10] CHANDLER, F. B., and MASON, I. C. Correspondence.

FIELD OBSERVATIONS

In the spring of 1932, a 14-acre field at Grand Junction, Mich., was set to highbush blueberries. The soil, a Saugatuck sand typical of those considered suitable for the growth of blueberries, had been well prepared for the plants, and tests for acidity and water-table determinations (12 to 36 inches) had revealed conditions favorable to growth. Nevertheless, 2 years after planting, many plants were missing, and by the spring of 1937 the the plants in an irregular area of 3 or 4 acres were dead (fig. 1). A thorough investigation of the soil was then made. The available nitrogen, phosphorus, potassium, and calcium content of the soil was as determined by Spurway's quick

FIGURE 1.—In foreground s shown one of the high acidity areas in the experimental blueberry field at Grand Junction, Mich.; many plants are missing and others are making very poor growth. In upper left corner is an area that received two applications of ground limestone, each equivalent to 2,000 pounds per acre; plants are making very satisfactory growth with an abundant cover crop.

tests.[11] The data obtained (table 1) indicated that these nutrients were present in quantities sufficient for good plant growth.

The pH values of the soil were extremely low (pH 3.2) in the areas where the plants were dead or dying (figs. 2, *A* and 4, *A*). However, inasmuch as Johnston [12] had grown plants successfully in soil with a pH value only slightly higher (3.4), this was not thought to be the cause of the poor growth and dying out of the plants, though from the soil tests (table 1, samples 1 and 2) the only apparent significant differences were in the pH values, and in the potassium and calcium content. It was therefore decided to undertake some greenhouse experiments and field trials in which various soil amendments would be used.

[11] SPURWAY, C. H. SOIL TESTING. A PRACTICAL SYSTEM OF SOIL DIAGNOSIS. Mich. Agr. Expt. Sta. Tech. Bul. 132, 16 pp. 1933.
[12] JOHNSTON, S. See footnote 4, p. 9.

TABLE 1.—*Soil analysis of a Saugatuck sand field, by the Spurway method; tests made in 1937*

Item		Sample 1 [1]	Sample 2 [2]	Sample 3 [3]
Reaction	pH	3.2	4.4	3.8
Nitrates	p. p. m.	5.0	5.0	20.0
Phosphorus	p. p. m.	1.0	1.0	.5
Potassium	p. p. m.	5.0	10.0	10.0
Calcium	p. p. m.	20.0	75.0	40.0
Ammonia	p. p. m.	2.0	2.0	
Iron		Trace	Trace	
Magnesium	p. p. m.		Trace	5.0
Organic matter		High	High	High

[1] Soil taken from near plant shown in figure 4, *A*.
[2] Soil taken from area in field where plants were making normal growth.
[3] Soil taken from near plant shown in figure 4, *B*. Sample was taken a year after treatment was applied.

EXPERIMENT 1

POT CULTURES

A quantity of soil representative of the area in which the plants had died, was taken from the field, screened, and throughly mixed. Three and one-half gallon galvanized-steel pails, coated on the inside with an asphalt paint, were filled to the same weight with the soil. A single 1-year-old, well-rooted cutting of the Rubel variety of blueberry was set in each pail. Pails were filled to allow for three replications for each treatment listed in table 2. The pails were then placed in the greenhouse, where they remained from April 1, 1937 until the middle of the following October. They were then removed to an outside shed where they remained during the winter.

TABLE 2.—*Schedule of fertilizer treatments in pot-culture experiments*

Treatment No.	Fertilizer material applied [1]					
	N	P	K	Mg	Mn	Ca
1	N	P	K			
2	N	P	K	Mg	Mn	Ca
3		P	K	Mg	Mn	Ca
4	N		K	Mg	Mn	Ca
5	N	P		Mg	Mn	Ca
6	N	P	K		Mn	Ca
7	N	P	K	Mg		Ca
8	N	P	K	Mg	Mn	
9	N	P	K			Ca

[1] N–P–K applied as a 5–10–5 mixture at the rate of 500 pounds per acre, Mg (magnesium sulfate), 50 pounds per acre; Mn (manganese sulfate), 50 pounds per acre; Ca (Limestone), 2 tons per acre.

On March 1, 1938, the plants were returned to the greenhouse to remain throughout the growing season. The temperature in the greenhouse was held fairly uniform at a mean of about 70° F. until the early part of the summer and thereafter was allowed to vary with the outdoor temperature. The amount of water that the soil would hold was determined by the Hilgard cup method and the moisture content was then kept as uniform as possible at 90 percent of the determined capacity, which was approximately 80 percent of field capacity. This was done by bringing the pots up to weight daily with distilled water.

Limestone [13] was applied at the rate of a ton per acre and was thoroughly mixed with the soil before the pots were filled. The following spring a second application of a ton per acre was made and

[13] Limestone and fertilizer treatments were calculated on the basis of the area of the pots rather than on the weight of the soil in the pots.

worked into the first inch or so of the soil. The other fertilizers were applied, after the buds started to break, to the surface of the soil to be carried down into it when watered.

The plants under treatment No. 1, in which magnesium, manganese, and limestone were withheld, and treatment No. 8, in which only limestone was withheld, started to grow normally and continued until about the first of July. At that time the tips of all the leaves on the terminal shoots began to show signs of burning. This burning was similar to that which had been observed under field conditions, beginning at the tips of the terminal leaves and finally progressing

FIGURE 2.—Blueberry plant (check) that received one application of N–P–K mixture; pH of soil 3.2. *B*, Plant that received one application of N–P–K mixture plus two applications of ground limestone, equivalent to 2,000 pounds per acre per application; pH of soil 3.9 at time picture was taken 2 years after treatment.

across the entire leaf. This condition developed progressively down the shoots to the older leaves, until by the latter part of August the plants were practically defoliated. All plants receiving limestone grew normally and showed no signs of either tip or marginal burning at any time during the growing season. The omission of magnesium or manganese, or both, had no noticeable effect upon the growth of the plants.

Figure 2, *A* and *B*, shows plants from treatments 1 and 9 respectively (table 2). These plants received the same applications of nitrogen, phosphorus, and potash, but the plant shown in *B* received, in addition, ground limestone equivalent to 2 tons per acre in two

applications, one at the time the soil was put into the pots, the other at the beginning of the second growing season. The soil reaction at

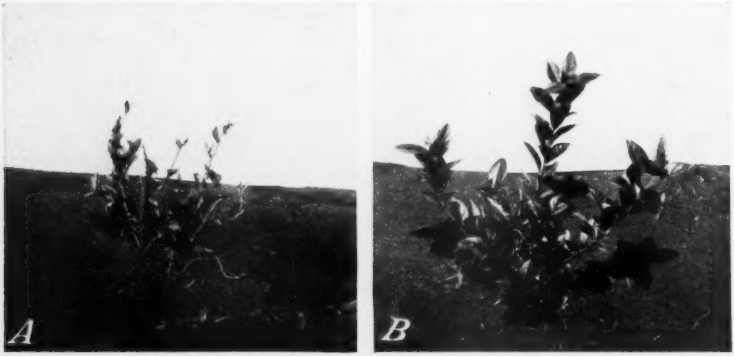


FIGURE 3.—*A*, Blueberry plant of Rubel variety growing in field given one application of muriate of potash; this plant is typical of the plants that received an application of muriate of potash either alone or in combination with nitrogen, phosphorus, or both. *B*, Rubel plant growing in check plot in the same area as the plant shown in *A*. Plants photographed the same day.

the beginning of the experiment was pH 3.2; at the time the photograph was taken the pH of the soil in figure 2, *A*, had not changed

FIGURE 4.—*A*, Six-year-old plant growing under field conditions. *B*, Two-year-old plant growing in soil in the same area as the plant shown in *A*. Both plants received the same fertilizer application, but the plant shown in *B* received in addition two applications of ground limestone, each application equivalent to 2,000 pounds per acre.

but that in figure 2, *B*, had risen to 3.9. The plant shown in figure 2, *B*, was typical of all plants growing in soil to which limestone had been applied.

Since nitrogen, phosphorus, and potash were present in this soil in sufficient quantities, the omission of these elements from the treatments (Nos. 3, 4, and 5) had no noticeable effect upon the growth of the plants.

FIELD TREATMENTS

In the field, the only fertilizer application made corresponded to treatment 9 in table 2. Two plots, each receiving the same treatment but in different locations, and each containing 110 plants (approximately one-tenth of an acre) were treated with a 5–10–5 fertilizer at the rate of 500 pounds per acre and an application of ground limestone at the rate of 1 ton per acre. The writer found under field conditions in Michigan that muriate of potash had a retarding effect, and in the majority of cases an injurious one, upon the plants. Figure 3, *A*, illustrates the effect of the muriate upon the plant. Figure 3, *B*, shows a plant that grew in the same area but received no fertilizer. The detrimental effect of muriate of potash was observed also by Collison [14] under conditions prevailing at Geneva, N. Y. Figure 4, *A*, shows a plant that was typical of those growing in the area where the plants were weak and dying. It is shown as it appeared July 26, 1938, in its sixth season of growth. The pH of the soil near this plant was 3.2, the same as the soil that was taken into the greenhouse and used in the pot cultures. Figure 4, *B*, shows a typical plant from the plots that had received two applications of ground limestone, each of 1 ton per acre. The pH of the soil near this plant had risen from 3.2 to 3.8. The two plants were photographed the same day. Although the plant in figure 4, *B*, was only in its second season of growth, it was much larger than the 6-year-old plant growing on the more acid soil.

EXPERIMENT 2

METHODS

The areas in Michigan that are most suitable for blueberry production consist of two types of soil, namely, Saugatuck sand and muck.[15] Both types were used in experiment 2.

A quantity of each soil was taken from the field into the greenhouse, where it was screened and thoroughly mixed. Three and one-half gallon galvanized-steel pails, as previously described, were filled with 47 pounds of the sand and 28 pounds of the muck. A single 2-year-old, well-rooted plant of the Rubel variety was set in each pail. A sufficient number of pails were filled with each soil to allow for four replications of each treatment, as follows:

Treatment No.	*Fertilizer*
1	No. fertilizer check.
2	Nitrate of soda (N).
3	Sulfate of ammonia (S).
4	Superphosphate.
5	Sulfate of potash.
6	Nitrate of soda + superphosphate.
7	Nitrate of soda + sulfate of potash.
8	Sulfate of ammonia + superphosphate.
9	Sulfate of ammonia + sulfate of potash.
10	Superphosphate + sulfate of potash.
11	Nitrate of soda + superphosphate + sulfate of potash.
12	Sulfate of ammonia + superphosphate + sulfate of potash.

[14] COLLISON, R. C. Unpublished data.

[15] These soils are hereafter referred to as sand and muck.

Throughout the experiment the plants were watered with distilled water and the pails were brought up to weight at each watering, thus eliminating as far as possible overwatering in some cases and underwatering in others. During the summer months the plants were kept out of doors in a frame house with open sides and an overhead protection of ordinary glass sash. During the winter months the roots were protected from excessive freezing by straw packed around the pails. The plants were grown in the pails throughout the first year without any fertilizer treatment in order to give all of them, insofar as possible, an equal start. At the beginning of the second growing season growth measurements were made and the plants were so arranged that the total growth of each of the groups of four plants which were to receive the different treatments varied no more than a few centimeters. Each group was then numbered from 1 to 12 and a fertilizer treatment assigned at random. The treatments were made on the basis of a 5–10–5 fertilizer applied at the rate of 500 pounds per acre. The second application was increased 50 percent over that of the previous season.

At the end of the third growing season, a sample of wood of the current season's growth was taken from each plant. As nearly as possible the same amount of wood was taken for each sample. This wood was cut into small pieces, placed in a drying oven and thoroughly dried at 70° C. It was then ground to pass through a 40-mesh sieve. Each ground sample was placed in a tightly stoppered bottle and was later analyzed for N, P_2O_5,andK_2O.

After the samples were taken for chemical analysis, the plants were cut off at the soil surface and the tops were thoroughly dried. The dry weights were then recorded.

Tables 3 and 4 present the complete data of the experiments, the former those for the dry-matter weight of the tops, and the latter, the percent of nitrogen, phosphoric acid and potash in the wood.

TABLE 3.—*Total oven-dry weight of top growth of 4 blueberry plants in 2 soils and in 12 fertilizer treatments*

SAND SOIL

Replication No.	Weight of top growth following fertilizer treatment No. —[1]											
	1	2	3	4	5	6	7	8	9	10	11	12
	Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
1	250	256	222	256	159	279	243	328	214	195	328	324
2	233	305	301	285	226	342	315	308	210	288	348	356
3	233	262	274	226	270	315	314	266	268	209	313	347
4	238	163	280	192	279	315	222	298	237	291	315	344
Average	238	246	269	240	234	313	273	300	232	246	326	343

MUCK SOIL

1	260	365	402	212	215	317	381	342	398	276	404	373
2	390	372	348	191	303	437	303	348	414	248	468	477
3	207	320	203	189	240	450	405	370	445	235	432	363
4	281	395	318	244	256	375	375	366	363	287	521	475
Average	284	363	318	209	253	395	366	356	405	261	456	422

[1] For explanation of fertilizer treatments, see text.

TABLE 4—*Chemical analysis of wood of 4 blueberry plants in 2 soils and in 12 fertilizer treatments*[1]

N IN PLANTS GROWN ON SAND SOIL

Replication No.	Analysis of wood of blueberry plants following fertilizer treatment No.—[2] [3]											
	1	2	3	4	5	6	7	8	9	10	11	12
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	0.617	0.924	0.834	0.548	0.709	0.701	0.789	0.737	0.836	0.651	0.859	0.559
2	.490	.842	.651	.627	.611	.716	.805	.761	.770	.576	.688	.697
3	.614	.708	.661	.571	.551	.657	.765	.696	.701	.764	.894	.723
4	.598	.668	.869	.472	.635	.776	.747	.763	.791	.620	.730	.714
Average	.580	.785	.754	.554	.626	.712	.776	.739	.774	.652	.634	.673

N IN PLANTS GROWN ON MUCK SOIL

1	0.521	0.621	0.643	0.523	0.564	0.415	0.667	0.660	0.716	0.567	0.688	0.585
2	.594	.631	.670	.408	.495	.661	.549	.635	.618	.538	.668	.577
3	.487	.663	.891	.578	.599	.598	.743	.583	.692	.521	.562	.604
4	.567	.661	.743	.616	.465	.643	.592	.647	.620	.559	.617	.607
Average	.542	.644	.736	.531	.531	.579	.638	.631	.661	.546	.634	.593

P_2O_5 IN PLANTS GROWN ON SAND SOIL

1	0.120	0.138	0.126	0.174	0.139	0.195	0.101	0.223	0.106	0.205	0.232	0.117
2	.118	.168	.109	.212	.157	.171	.099	.227	.102	.217	.229	.214
3	.120	.092	.102	.181	.102	.216	.112	.190	.117	.237	.229	.234
4	.135	.083	.149	.223	.122	.202	.117	.218	.117	.196	.233	.194
Average	.123	.120	.121	.197	.130	.196	.107	.214	.110	.214	.231	.190

P_2O_5 IN PLANTS GROWN ON MUCK SOIL

1	0.110	0.095	0.118	0.200	0.112	0.163	0.105	0.234	0.078	0.238	0.229	0.265
2	.123	.109	.096	.154	.096	.243	.103	.228	.091	.228	.274	.253
3	.087	.200	.113	.186	.115	.209	.106	.223	.103	.188	.226	.245
4	.117	.088	.109	.215	.080	.187	.127	.230	.096	.216	.247	.251
Average	.109	.123	.109	.189	.101	.200	.110	.229	.092	.217	.244	.253

K_2O IN PLANTS GROWN ON SAND SOIL

1	0.325	0.253	0.265	0.345	0.590	0.250	0.398	0.283	0.612	0.611	0.488	0.450
2	.265	.291	.306	.355	.536	.233	.376	.317	.434	.744	.468	.546
3	.363	.213	.320	.414	.508	.318	.424	.326	.470	.686	.471	.555
4	.302	.197	.289	.477	.608	.325	.259	.267	.541	.606	.447	.452
Average	.314	.238	.295	.398	.560	.281	.364	.298	.514	.662	.468	.501

K_2O IN PLANTS GROWN ON MUCK SOIL

1	0.317	0.263	0.266	0.393	0.333	0.230	0.485	0.236	0.426	0.519	0.467	0.559
2	.296	.285	.280	.251	.438	.293	.477	.256	.454	.491	.533	.429
3	.270	.267	.308	.377	.344	.253	.436	.245	.390	.403	.432	.496
4	.294	.334	.284	.333	.263	.297	.414	.301	.466	.500	.499	.445
Average	.294	.287	.284	.338	.344	.268	.453	.259	.434	.478	.483	.482

[1] Analysis made by Dr. E. J. Miller and staff, Department of Chemistry, Michigan Agricultural Experiment Station.
[2] For explanation of fertilizer treatments see text.
[3] Percentages given are on dry-weight basis.

RESULTS

The experiments were so designed that Fisher's method of analysis of variance could be used to test significance, and this analysis was made. The use of fertilizer treatments in general gave very signifi-

cant effects on the growth of the blueberry plants in both Saugatuck sand and muck soil. In a further analysis made to determine which particular element or combination of elements was responsible for the increased growth, nitrogen and phosphorus were found most effective when applied to the sand and nitrogen and potash when used on the muck. The effect of applications of nitrogen and phosphorus on total growth was significant at the 1-percent point for the plants growing in the sand; potash had no apparent beneficial effect.

The rank correlation between nitrogen accumulation in the wood and total growth of blueberry plants in the sand was 0.90 ± 0.06 and

FIGURE 5.—*A*, Plants growing in sand with no fertilizer (check); *B*, plants growing in sand with complete fertilizer. The check plants matured earlier than those receiving the complete fertilizer and the lateral branches on the shoots were not so extensive. Photographing delayed until defoliation was almost complete so as to give a better conception of the character of growth.

between phosphorus and total growth, 0.75 ± 0.13, while for potash it was 0.18 ± 0.28. The corresponding rank correlation coefficients for plants grown in the muck were: Nitrogen, 0.93 ± 0.04; phosphorus, 0.63 ± 0.18; and potash, 0.87 ± 0.07. There is a direct relation between total growth and accumulation of nitrogen and phosphorus in the wood of plants grown in the sand and between total growth and nitrogen and potash content of plants grown in the muck. Inasmuch as potash did not benefit the plants, from the standpoint of total growth in the sand, and phosphorus did not benefit the plants in the muck, the accumulation of these two elements in the wood of the plants on those soils could be classed as "luxury consumption."

The analysis of the data indicated that the application of neither phosphorus, potash, nor, a combination of the two increased the percentage of nitrogen in the wood. Further, neither nitrogen nor

potash applications nor their combination increased the percentage of phosphorus in the wood. Nitrogen applications did exert a significant effect on the accumulation of potash in the wood of plants grown on the sand, but no significant effect on plants grown on the muck.

DISCUSSION

Observation and experience have demonstrated that in the main two types of soil, namely, muck or peat and sandy muck or sand containing a rather high percentage of organic matter, are suitable

FIGURE 6.—*A*, Plants growing in muck with no fertilizer (check); *B*, plants growing in muck with complete fertilizer. The check plants matured earlier than those receiving the complete fertilizer and growth was more spindly and sparse. Photographing delayed until defoliation was almost complete so as to give a better conception of the character of growth.

for blueberry culture; further, that blueberry plants thrive naturally in both types of soil, that in both types there is considerable variation in amount of growth (figs. 5 and 6), and that, in general, productivity and yields follow fairly closely the amount of growth and the size of plant.

What appeared to be average or typical soils of these two types were employed in this study. In composition, the soils differ greatly from each other as the muck or peat is of organic origin while the sand or sandy muck is of mineral origin though containing much organic material. This study corroborates the findings of others in showing that the blueberry plant is very sensitive to differences in soil acidity when the lower limits of tolerance are approached, and indicates that

attention to soil reaction is of first importance when plants are not making normal growth.

This study also shows that available nutrients may be a limiting factor of secondary importance, though it does not point to any one nutrient element as most likely to be lacking or deficient in either a muck or a sandy muck soil. Unless or until there is definite evidence in any patricular case that some one nutrient element is the limiting factor the only safe course is to use a complete fertilizer mixture, consisting of nitrogen, phosphorus, and sulfate of potash.

SUMMARY AND CONCLUSION

In the soil under test, pH 3.2 was below the limit for vigorous growth of blueberry plants.

Symptoms associated with too high acidity are leaf scorch, which begins at the leaf margins and progresses across the leaf, resulting in defoliation. This may be followed by stunting and finally by death of the plants.

Applications of lime sufficient to raise the pH of th soil from 3.4 to 3.8 prevented leaf scorch and resulted in normal growth.

A positive correlation was found between total growth of plants and total milligrams of nitrogen and phosphorus in the tops of the plants grown in the sand and between total growth of plants and nitrogen and potash content of plants grown in the muck.

Muriate of potash should be omitted from the complete fertilizer mixture.

POTATO VARIETIES IN RELATION TO BLACKENING AFTER COOKING[1]

By G. H. RIEMAN, *professor of genetics, horticulture, and plant pathology,* W. E. TOTTINGHAM, *associate professor of biochemistry,* and JOHN S. MCFARLANE, *instructor in genetics and economic entomology, Wisconsin Agricultural Experiment Station*

INTRODUCTION

Blackening after cooking is regarded as one of the commonest defects of the potato (*Solanum tuberosum* L.). Spangler (*10*)[2] found that 7 percent of 1,165 Chicago retailers listed tendency to "cook black" as the most serious defect of potatoes and nearly 18 percent listed it as the second most objectionable defect. Hotchkiss et al. (*3*) report cooking black as the commonest complaint of 880 retailers in the cities of Cleveland and Rochester.

During the past 40 years numerous studies have been made on the relation of conditions of growth to darkening in potato tubers. However, the control of this defect is still an important problem in many potato-producing regions. Ashby (*1*), working in England, noted a marked influence of climatic factors, such as seasonal rainfall and air temperature, on the ability of various types of soil to produce potatoes free from darkening. Other investigators have observed similar climatic effects. Tottingham, Nagy, and Ross (*11*) reported that blackening was particularly serious in crops produced during growing seasons characterized by excessive heat and drought. Nash and Smith (*6*) suggested that lack of sufficient sunlight and low temperatures may be important in influencing the occurrence of blackening. More recently Smith, Nash, and Dittman (*9*) observed that tubers maturing under low temperatures ranging from 50° to 60° F. were likely to blacken, whereas those maturing at higher temperatures ranging from 70° to 80° seldom showed discoloration. They also noted that high storage temperatures for 3 to 4 days prevented blackening.

Nutritional factors in relation to blackening have received considerable attention from American and European investigators during the past 15 years. Although these studies have made many valuable contributions to the knowledge of the nutritional requirements of the potato plant, they have not led to a definite understanding of the causes of blackening in cooked potatoes. As a matter of fact, it has not been possible thus far to induce blackening with certainty under controlled experimental conditions by varying any environmental factor.

Varietal response to blackening has received but little attention from workers interested in this problem. Parker (*7*) stated that color after cooking is influenced by soil rather than variety. Nash

[1] Received for publication April 12, 1943. Contribution from the Departments of Genetics (paper No. 313), Horticulture, Plant Pathology, Biochemistry, and Economic Entomology, Wisconsin Agricultural Experiment Station. Photographs taken by Eugene H. Herrling, Department of Plant Pathology, Wisconsin Agricultural Experiment Station.

[2] Italic numbers in parentheses refer to Literature Cited, p. 31.

(*5*) found that Green Mountain, Pioneer Rural, and Sebago tubers blackened most seriously, and Houma, Pontiac, and Chippewa blackened least.

The object of the present study was to examine certain possible relation ships between the genetic constitution of the potato plant and the blackening character frequently observed in cooked potato tubers.

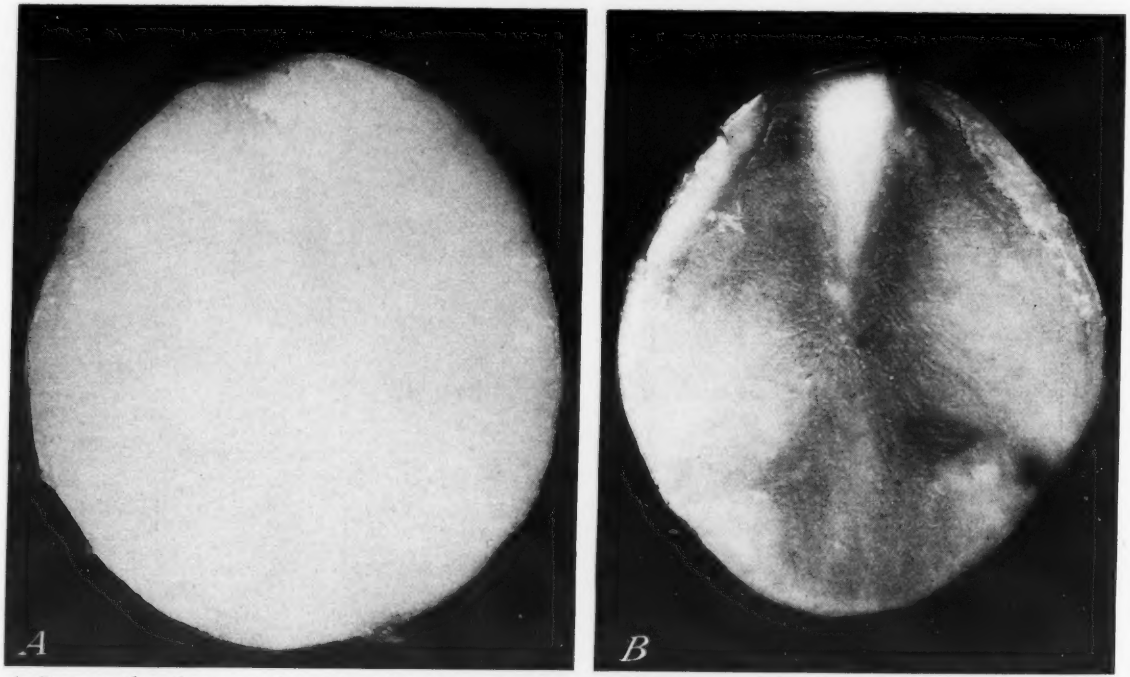
PLANT MATERIALS AND METHODS

Twenty-three varieties and strains of potatoes were grown in nine widely separated locations in Wisconsin during the 5-year period 1937–41. These test plots were located on four general soil types, as follows: Three on clay loam, two on sandy loam, two on silt loam, and two on muck. The seed, for the most part, was produced in tuber-unit plots in the extreme northern part of the State, placed in suitable common storage, and divided equally for the various test plots. The test plots were planted during the last 2 weeks in May and the first week in June. They were harvested during the last 2 weeks in September and the first week in October. All of the varieties at a given location were planted at the same time and harvested at the same time. Four 25- or 50-hill single-row randomized replicates of each variety were grown at each location. Yield records were taken on each replicate. A composite sample for boiling tests was drawn from the four replicates and placed in common storage at about 42° F. The boiling tests were made approximately 2 months after harvest. Nine hundred sixty-eight boiling tests were made during the course of this study.

The essential features of the cooking method were held constant for the 5-year period of the experiment. Ten-tuber samples of fairly uniform size were washed and cooked with the skins intact during the first 2 years, but during the last 3 years the samples were peeled and washed in an abrasive machine. The tubers were cut in halves longitudinally and placed in uniform aluminum cooking vessels containing similar amounts of cold tap water. The usual kitchen method of trial with a knife or fork was used to determine when the potatoes were cooked. Obvious errors in judgment in the cooking process were corrected by boiling another sample. The cooked halves were placed flat face upward on filter paper and allowed to cool for approximately a half hour at room temperature before color readings were made. The flat cut surfaces, exposing longitudinal sections through the center of the tubers, were used to determine the amount of blackening. Color readings were made under a fluorescent lamp in a compartment painted black internally. The tubers in a sample were classified as follows: 1=white; 2=light gray; 3=medium gray; 4=dark gray, as indicated in plate 1. Photographs showing the amount of blackening allowed for each class were used as standards.

Blackening indices were calculated for each variety grown at each location whereby equal weight was given to the four blackening classes and a range established from 0 for all white tubers to 100 for all dark-gray tubers.[3]

[3] Blackening index=Number of tubers in classes 1, 2, 3, 4 multiplied by 0, 1, 2, 3, respectively. Sum of these products divided by the product of 3 times the number of tubers. This quotient multiplied by 100=Blackening index.



A, Cross section through a Triumph potato tuber showing no blackening one-half hour after boiling. Classification, white or class No. 1. *B*, Cross section through a Russet Rural potato tuber showing considerable blackening one-half hour after boiling. Classification, medium gray or class No. 3.

An attempt was made to determine the optimum stage for the expression of blackening in stored potatoes. The least amount of blackening after boiling was observed at the time of harvest while the greatest amount was noted in the spring after 5 months storage when the tubers were soft and heavily sprouted. Classification of blackening after boiling became progressively more variable as sprouting activity increased. The most uniform results in measuring the amount of blackening—as judged by duplicate 10-tuber tests—were obtained on dormant tubers held in storage at 42° F. for a period of approximately 2 months.

RESULTS

VARIETIES AND STRAINS IN RELATION TO BLACKENING

A study of the data in table 1 shows that although blackening was markedly affected by seasonal growing conditions, the general order of varietal response was maintained during the 5-year period of the test. Among the first nine varieties which have been tested each year, Triumph and Chippewa exhibited definite tendencies to cook white with low 5-year average blackening indices of 20 and 22, respectively. Rural New Yorker and Russet Rural showed a consistent tendency to cook dark with high 5-year average blackening indices of 46 and 49, respectively, or about twice the amount of blackening observed in Triumph and Chippewa. The remaining five varieties in this group—Houma, Katahdin, Red Warba, Irish Cobbler, and Green Mountain—showed intermediate reactions with blackening indices ranging from 29 to 41. The six varieties in the second group which were tested only during the first three seasons—Earlaine, 100 Day Cobbler, Pioneer Rural, Mesaba, Russet Burbank, and Columbia Russet—all produced considerable amounts of blackening. The four varieties in the third group which were tested during different seasons—White Blossom Cobbler, Sebago, Pontiac, and Sequoia—produced various amounts of discoloration.

TABLE 1.—*Blackening after boiling of tubers of 19 potato varieties and strains grown in 9 Wisconsin counties*

Variety or strain	Average blackening indices for cooked samples[1]						
	1937	1938	1939	1940	1941	3-year average 1937–39	5-year average 1937–41
Triumph	57	17	11	6	9	28	20
Chippewa	57	30	9	8	7	32	22
Houma	67	30	20	19	9	39	29
Katahdin	52	33	30	23	13	38	30
Red Warba	76	38	7	13	14	40	30
Irish Cobbler	76	63	26	10	17	55	38
Green Mountain	71	67	32	21	14	57	41
Rural New Yorker	81	59	37	31	24	59	46
Russet Rural	83	70	37	35	21	63	49
Earlaine	72	33	24			43	
100 Day Cobbler	77	56	39			58	
Pioneer Rural	76	56	39			57	
Mesaba	81	56	39			59	
Russet Burbank	67	67	33			56	
Columbia Russet	76	75	30			60	
White Blossom Cobbler	81	63					
Sebago		11	13	4	6		
Pontiac			17	13	14		
Sequoia					16		

[1] Blackening index: 0=white ½ hour after boiling; 100=dark gray ½ hour after boiling.

Of the 19 varieties listed in table 1, 6 were early-maturing, 2 were midseason, and 11 were late-maturing. Varieties with a tendency to cook white and varieties with a tendency to cook dark were observed in all 3 maturity classes.

Clonal selections derived from standard varieties behaved like the parental stocks. Pioneer Rural, a New York clonal selection out of Russet Rural, produced similar amounts of blackening during three seasons. Another New York clonal selection under test for three seasons, 100 Day Cobbler out of Irish Cobbler, behaved like its parental variety. Columbia Russet, a periclinal chimera apparently derived from Green Mountain, produced blackening in amounts similar to Green Mountain over a 3-year period. The Minnesota periclinal chimera Red Warba, out of the pink-eyed Warba, produced similar results during one season. White Blossom Cobbler cooked like Irish Cobbler for 2 years, although in this case a clonal relationship between the two varieties has not been clearly established. The periclinal chimera Russet Rural, out of Rural New Yorker, developed similar amounts of blackening during the 5-year period of the experiment. Four varieties and strains which were tested for only 1 year at the nine locations have been omitted from table 1. These include the New York Rural strain Toanco No. 4, the Wisconsin Rural strain Martin Seedling, the New York Irish Cobbler strain Cottrell Cobbler, and the Minnesota variety pink-eyed Warba already mentioned. The behavior of Toanco No. 4 and Martin Seedling was similar to that of the two standard Rural varieties. Cottrell Cobbler developed the same amount of blackening after cooking as the standard Irish Cobbler variety.

The new Sebago variety tended to produce white-cooking tubers for a 4-year period; the new variety Pontiac tended to produce intermediate-colored tubers in cooking tests for 3 years. These results indicate that breeding for varieties having a tendency to cook white may be accomplished since the parents of these varieties, Chippewa, Katahdin, and Triumph, all have favorable cooking records.

HYBRID POPULATIONS IN RELATION TO BLACKENING

Additional evidence on the mode of inheritance of blackening after cooking is presented in table 2. Two F_1 populations resulting from crosses between the Sebago or Katahdin varieties, which tend to cook white, with the Hindenburg variety, which tends to cook dark, were tested for one season according to the procedure previously described. Normal-sized second clonal generation tubers were planted in Bayfield County during the middle of June 1941 and harvested while the vines were still green during the second week in October. Less than 1 percent of the vines were mature at harvest time. Two hundred and sixty-seven F_1 individuals were classified on the basis of approximately 5 tubers per cooked sample in place of the customary 10-tuber samples. The distributions of the 2 F_1 populations resulting from Sebago $\times$ Hindenburg and Katahdin $\times$ Hindenburg were similar. The F_1 populations were extremely variable. An array of F_1 individuals ranged throughout the blackening scale, which exceeded the limits observed for the 3 parental varieties. Seventy-six percent of the segregates from the 2 crosses resembled the 2 parents which tend to cook white, 14 percent developed the same amount of blackening as the dark-cooking parent, and 10 percent exhibited more blackening than the dark-cooking parent.

TABLE 2.—*Blackening after boiling of tubers of 3 parental potato varieties and 2 F_1 populations*

Stock	Segregates	Total tubers	Blackening classes[1]			
			White to light gray (BI range, 0–24)	Light gray (BI range, 25–49)	Medium gray (BI range 50–74)	Dark gray (BI range, 75–100)
	Number	*Number*				
Sebago		10	1			
Katahdin		10		1		
Hindenburg		10			1	
Sebago × Hindenburg	131	735	51	48	20	12
Katahdin × Hindenburg	136	791	58	45	18	15

[1] BI = Blackening index.

LOCATION IN RELATION TO BLACKENING

The results of cooking tests conducted over a period of 5 years on nine varieties grown in nine potato-producing counties in Wisconsin are presented in table 3. All locations produced large amounts of black-

TABLE 3.—*Blackening after boiling of tubers of 9 potato varieties grown in 9 Wisconsin counties*

County and soil series	Blackening index[1] in—				
	1937	1938	1939	1940	1941
Walworth: Muck [2]	56	41	17	9	1
Washington: Miami clay loam	66	44	13	17	7
Door: Miami loam	74	48	22	17	8
Langlade: Antigo silt loam	78	63	20	13	30
Oneida: Vilas sandy loam	85	41	28	28	19
Waushara: Waukesha sandy loam	59	56	33	26	13
Portage: Muck [2]	62	48	15		21
Kenosha: Carrington clay loam		42	20	15	5
Barron: Spencer silt loam		22	39	22	21
Average	69	45	23	18	14

[1] Averages for 9 varieties: 0 = white ½ hour after boiling; 100 = dark gray ½ hour after boiling.
[2] Soil not classified.

ening during the hot, dry growing season of 1937 and small amounts during the cool, wet growing seasons of 1940 and 1941. However, the maturing and harvesting seasons during the last 2 weeks in September and the first week in October were cooler in 1937 than in 1940 and 1941. The southern stations in general produced somewhat less blackening than the northern stations. For potatoes grown on muck soil in southern Walworth County the average blackening index for the 5-year period was 25, while for the potatoes grown on sandy loam soil in Oneida County at a higher elevation and approximately 200 miles farther north, the average blackening index was 40.

SEASON IN RELATION TO BLACKENING

The data in table 3 show a definite seasonal influence on blackening. A high average blackening index of 69 was recorded in 1937 for nine varieties at seven locations. Lower blackening indices were recorded for the same nine varieties during each succeeding year extending to 1941, when the average blackening index dropped to 14 for nine locations. During the 5-year period of this experiment the first two seasons rep-

resented heavy blackening years in Wisconsin while the last three seasons represented nonblackening years. These results agree with the experience of the trade with stored potatoes during the 1937 to 1941 period. Beginning with the 1939 crop, a minor change was made in the cooking technique which may account for some, but not all, of the difference in blackening observed between the first 2 years and the last 3 years of the experiment. In 1937 and 1938 the tubers were boiled with the skins intact while in the remaining 3 years they were washed and partly peeled with an abrasive machine.

A series of correlation studies was made on the effect of temperature, precipitation, and cloudy days during the five growing and harvesting seasons on the occurrence of blackening. Weather records collected by official weather stations located near each of the nine test plots and published by the United States Department of Commerce were used in this study. No significant associations were observed between either precipitation or cloudy days and the incidence of potato blackening. The associations between mean monthly air temperatures during the growing and harvesting period and the occurrence of blackening are of unusual interest. A nonsignificant low negative correlation was found when the mean air temperatures for the 4 months June, July, August, and September were averaged. However, when the mean air temperatures for single months were considered, two significant negative correlations and one significant positive correlation were found between air temperature and occurrence of blackening (table 4)

TABLE 4.—*Correlations between mean monthly air temperatures during the months of the growing and harvesting season and the occurrence of blackening in potatoes*

Month	*r* value	*P* value
June	−0.5	0.01
July	−.2	.50
August	+.4	.02
September	−.5	.01
June, July, August, September	−.2	.50

DISCUSSION AND CONCLUSIONS

Potato blackening after cooking is attributed by Merkenschlager (*4*) to an accumulation of tyrosine and unusual activity of tyrosinase. Tottingham, Nagy, and Ross (*11*) and Ross and Tottingham (*8*) have observed an association of the blackening abnormality with instability of protein and greater activity of the tyrosinase system in the potato tuber. The presence of an activator or activators of the oxidation of tyrosine was found in tubers which discolored after cooking and was absent from tubers which remained white after cooking. The amount of a substance or substances giving the catechol reaction in potatoes after about 3 months in cold storage has been found by Clagett and Tottingham (*2*) to be correlated to a considerable extent with the degree of blackening after boiling. Such studies have shown that these biochemical relationships, responsible in part at least for the occurrence of blackening in cooked tubers, are greatly influenced by conditions of growth and storage. That they may also be profoundly influenced by the genetic constitution of the potato plant is demonstrated in the present study.

GENETIC INFLUENCES

Genetic differences responsible for variations in the development of dark pigments in cooked tubers are common among American cultivated potato varieties. This is shown by the wide differences observed among nine varieties selected at random for blackening studies. Of these nine varieties which were tested for five seasons at nine widely separated locations, the two whitest-cooking varieties, Triumph and Chippewa, produced on an average only about one-half as much blackening as the two darkest-cooking varieties, Russet Rural and Rural New Yorker. Fourteen additional varieties have been tested in a similar manner for from one to four seasons. The new Sebago variety included in this group maintained an exceptionally white-cooking record over a 4-year period, but no variety observed was immune to blackening after cooking. A general grouping of 22 varieties and strains may be made in 3 classes as shown in table 5.

An examination of the varieties listed in these three classes in respect to maturity indicates that this variable was relatively unimportant in the development of black pigment since both late- and early-maturing varieties were observed in all three classes. It is of interest to note here that the three varieties listed in the white-cooking class present an unusually wide range in maturity. In this study, Triumph was consistently classified as a first early variety. As a rule, Chippewa was classified as a midseason variety, although in a number of cases it was inclined to be late. In all cases, Sebago was classified as an extremely late variety.

TABLE 5.—*General grouping of 22 varieties and strains of potatoes according to their tendency to cook white, intermediate, or gray*

Tendency to cook white	Tendency to cook intermediate	Tendency to cook gray
Triumph	Houma	Irish Cobbler
Chippewa	Katahdin	Cottrell Cobbler
Sebago	Red Warba	100 Day Cobbler
	Warba	White Blossom Cobbler
	Earlaine	Green Mountain
	Pontiac	Columbia Russet
		Rural New Yorker
		Russet Rural
		Pioneer Rural
		Martin Seedling
		Toanco No. 4
		Mesaba
		Russet Burbank

Eight, and possibly nine, of the 22 varieties listed in table 5 represent clonal selections out of Rural New Yorker, Irish Cobbler, Green Mountain, and Warba varieties. Three of the clonal selections appear to be identical with their parental varieties while the others differ from their parents in one or more plant characteristics. Four of them are periclinal chimeras. Since the clonal selections were probably made on the basis of characteristics other than cooking quality and since it is known that their genetic constitutions are similar to those of their parents, they should react like their parents in cooking tests.

The parent-offspring comparisons in table 6 clearly show that this is the case.

TABLE 6.—*Comparison of the cooking qualities as indicated by average blackening indices, of parental varieties of potatoes and their clonal selections*

Years tested	Parental variety	Average blackening index	Clonal selection	Average blackening index
1939	Warba	10	Red Warba	7
1937	Irish Cobbler	76	Cottrell Cobbler	86
1937–38	do	70	White Blossom Cobbler [1]	72
1937–39	do	55	100 day Cobbler	58
1937–41	Rural New Yorker	46	Russet Rural	49
1937–39	do	59	Pioneer Rural	57
1937	do	81	Martin Seedling	81
1937	do	81	Toanco No. 4	78
1937–39	Green Mountain	57	Columbia Russet	60

[1] Clonal relation to Irish Cobbler not clearly established.

The fairly close agreements between the clonal selections and the parental varieties from which they were derived not only demonstrate the relative unimportance of clonal strains in respect to blackening but they also indicate reasonable reliability in the testing techniques employed. Breeding for varieties with a definite tendency to cook white may be accomplished in the light of the behavior of the varieties considered in this investigation. If the 8 or 9 clonal selections are omitted, it will be noted that from a small sample of about 13 varieties selected at random 3 were found which had a tendency to cook white, 5 appeared to be intermediate in their behavior, and 5 had a tendency to cook dark. Two of the three varieties which exhibited white-cooking tendencies are closely related. The white-cooking Chippewa variety is one of the parents of the white-cooking Sebago variety. The inheritance of a physicochemical system, possibly the tyrosinase system, responsible for differences in the formation of dark melanin-like pigments in cooked potato-tuber tissue is suggested by the parent-offspring relationships of the following varieties:

Parents	*Offspring*
Chippewa (white) × Katahdin (intermediate)	Sebago (white).
Triumph (white) × Katahdin (intermediate)	Pontiac (intermediate).
Green Mountain (dark) × Katahdin (intermediate)	Sequoia (dark [4]).

The one common parent in these three crosses, Katahdin, has been classified as an intermediate variety. Its cooking behavior over a 5-year period places it in a borderline position between the white-cooking and intermediate-cooking classes. The white and intermediate varieties developed from Katahdin crosses indicate that this parent may carry genes for white-cooking quality. More definite genetic evidence for this assumption is furnished by the behavior of an F_1 population resulting from a cross between Katahdin and the dark-cooking Hindenburg variety recorded in table 2. Out of a population of 136 F_1 individuals, 58 produced less pigment than Katahdin, 45 reacted the same as Katahdin, while 18 behaved like the dark-cooking Hindenburg parent and 15 produced more pigment than the dark-cooking parental variety. A similar F_1 distribution was obtained from a cross between Sebago and Hindenburg. The progenies from both crosses exhibited transgressive inheritance with large representa-

[4] The Sequoia rating is based on only 1 year's results at 9 locations. Its behavior suggests a borderline position between the intermediate-cooking and dark-cooking classes.

tions of F_1 individuals on the white-cooking end of the blackening scale. These results show that white tuber flesh after cooking is dominant or incompletely dominant to gray tuber flesh after cooking, and that the genetic factorial interactions may be comparatively simple since the parental types were easily recovered in small populations of F_1 individuals. Segregation in the F_1 generation also shows that the varieties used in these crosses are heterozygous for genes controlling gray pigment formation in cooked potato-tuber tissue.

ENVIRONMENTAL INFLUENCES

Seasonal variations in growing and harvesting conditions certainly caused wide fluctuations in the incidence of blackening after cooking throughout the period of this study. This is clearly shown by the average blackening indices recorded in table 3 for nine varieties grown at nine widely separated locations. Almost a complete range of the blackening scale is represented with the high blackening index of 85 recorded for Oneida in 1937 and the low blackening index of 1 recorded for Walworth in 1941.

Climatic factors exerted a much greater influence on the incidence of blackening than soil types. Potatoes grown on the different soil types listed in table 3 all had comparatively high average blackening indices in 1937 and low blackening indices in 1941. In general, the potatoes grown on muck soils showed somewhat less blackening than those grown on upland mineral soils. Soil fertility levels, as indicated by potato yields, appeared to play a minor role in the development of potato blackening.

Air temperature appeared to be one of the most important environmental factors involved in after-cooking blackening. Low air temperatures during the months of June and September and high air temperatures during the month of August appeared to be associated with the development of blackening in this series of field experiments. These findings agree in part with the early field observation of Tottingham, Nagy, and Ross (*11*), who reported serious blackening difficulties in crops produced under high temperatures, and the conflicting field observation of Smith, Nash, and Dittman (*9*), who recently reported increased blackening of tubers which matured under low temperatures. Considerable progress might be made in an understanding of the nature of potato blackening after cooking by studying the relations between temperature and the occurrence of the blackening defect under controlled environmental conditions.

It is probable that some of the differences in amounts of blackening observed between varieties was due to environmental rather than genetic influences. Varieties of different maturities were planted at the same time at each location. Frequently the early-maturing varieties ripened during the hot month of August while the late-maturing varieties ripened during the latter part of September when the weather was usually much cooler. Judging from the observations made by Smith et al. (*9*), and partially substantiated in this study, it might be expected that the early-maturing varieties would tend to cook white while the late-maturing varieties would tend to cook dark. However, the varietal comparisons presented in table 1 show that this is not the case. Among the 6 early-maturing varieties, Triumph has a tendency to cook white, Red Warba and Earlaine are intermediate, while Irish

Cobbler, Mesaba, and White Blossom Cobbler have a tendency to cook dark. Of the 2 midseason varieties, Chippewa has a tendency to cook white and 100 Day Cobbler has a tendency to cook dark. The remaining 11 late-maturing varieties are distributed similarly to the early-maturing varieties with respect to cooking tendencies (table 7).

TABLE 7.—*Distribution of the 19 early, midseason, and late varieties of potatoes listed in table 1 according to their tendency to cook white, intermediate, or dark*

Variety group	Tendency to cook—		
	White	Intermediate	Gray
Early	1	2	3
Midseason	1	0	1
Late	1	3	7

In connection with these results the high positive correlation between mean air temperature during the month of August and the incidence of blackening may be important. The delay in harvesting the early-maturing varieties until late in the fall when the late-maturing varieties ripened may also have a bearing on the occurrence of blackening, since it is not known how or when the blackening mechanism operates. The conditioning of potatoes in storage had a marked effect on blackening. Freshly harvested samples which were held at room temperature for a few weeks prior to boiling frequently exhibited much less blackening than did comparable lots held in cold storage at 42° F. for a period of 2 months or more. These results substantiate the findings of Smith, et al. (*9*), who reported that high temperatures in storage for 3 to 4 days prevented blackening.

SUMMARY

Consistent differences in amounts of blackening after boiling were observed among 23 potato varieties and strains grown over a period of 5 years at 9 widely separated locations in Wisconsin. The 2 whitest-cooking varieties, Triumph and Chippewa, exhibited only one-half as much blackening as the 2 dark-cooking varieties, Rural New Yorker and Russet Rural. Eight named varieties developed through clonal selection behaved similarly to their parental varieties.

The white-cooking tendencies shown by the closely related Chippewa, Katahdin, and Sebago varieties suggest that these varieties carry genetic factors for white tuber flesh after boiling. The behavior of F_1 progenies derived from Katahdin and Sebago crossed with the dark-cooking Hindenburg variety supports this assumption. White tuber flesh after cooking was dominant or incompletely dominant to gray tuber flesh after cooking. Parental types were readily recovered among 267 F_1 individuals, indicating simple factorial interactions for after-cooking blackening. Segregation in the F_1 generation demonstrated heterozygosis in the parental stocks.

This study indicates that the dark-cooking character is inherited. By the breeding of potato varieties showing white tuber flesh after boiling this factor may be partially controlled.

Climatic factors exerted a profound influence on the formation of substances in potato tubers which turn dark after boiling, but the influence of soil type and soil fertility on the blackening process was limited. The conditioning of potatoes in storage had a marked effect on blackening.

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CHEMICAL COMPOSITION OF SOME AMERICAN WILD FEEDSTUFFS[1]

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INTRODUCTION

In recent years much interest has been manifested in the conservation of wildlife. As a result, some work has been done to ascertain which wild plants will produce the largest and most nutritious supply of feed for wildlife, especially during the winter months, and to encourage the propagation of those feeds that hold the most promise. This work may be of value in the feeding of domestic animals, including poultry, when there is a shortage of farm crops. Although feeding tests are necessary in order to obtain the actual nutritive value of wild feedstuffs for domestic animals, data on their proximate composition will serve as a guide in indicating their probable nutritive value. A review of the literature shows that there is little information on the composition of wild feedstuffs.

Winton and Winton (*13*)[3] have compiled data on a few wild feedstuffs, but in many cases these data are not comprehensive enough to be of much value. Wehmer (*12*) made a fairly comprehensive compilation of wild feedstuffs found in Germany. Morrison (*9*) included, in his well-known tables of the composition of cultivated plants, the results of some analyses of a few wild feedstuffs. Recently Wainio and Forbes (*11*) published data on the proximate composition of 35 wild fruits and nuts. Bailey (*2, pp. 417–418*) reported the analyses of 62 native grains, seeds, and berries. A number of studies have been made of the chemical composition of wild plants and their seeds for the purpose of obtaining data on their pharmacological properties, but these data are, in most cases, of little or no value from the standpoint of animal nutrition.

The study reported here was undertaken for the purpose of obtaining more information on the composition of wild feedstuffs. The data should be useful in the fields of soil conservation, wildlife conservation, and animal nutrition. This work was conducted at the United States Department of Agriculture, Beltsville Research Center, Beltsville, Md., by the Bureau of Animal Industry, the Bureau of Biological Survey (formerly a bureau of the United States Department of Agriculture but now a part of the Fish and Wildlife Service of the United States Department of the Interior), and the Virginia Polytechnic Institute.

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[2] The authors are indebted to Harry W. Titus, of the Bureau of Animal Industry, to Ralph B. Nestler and W. W. Bailey, who were employees of the Bureau of Animal Industry when this work was done, and to A. L. Nelson, of the Fish and Wildlife Service, Department of the Interior, for their assistance, advice, and helpful criticism.
[3] Italic numbers in parentheses refer to Literature Cited, p. 46.

SOURCE OF SAMPLES AND METHODS USED

The samples of wild feedstuffs were obtained from several sources. Most of them were collected by the Bureau of Biological Survey during the fall of 1939 in various national forests, nurseries of the Soil Conservation Service, and forests of the Tennessee Valley Authority. Others were collected by the senior author during the fall and winter of 1939 and the spring of 1940. Some were purchased on the open market. Four were collected by Philip Barske of Ann Arbor, Mich., during the fall of 1940. The time of collection shown in table 1 is as accurate as it was possible to obtain from the records of the collectors. Additional information concerning the collection of the samples is recorded in table 1. The samples were classified as follows: (1) Legume seeds, (2) grass seeds, (3) miscellaneous seeds, (4) mast, (5) fruits, and (6) tubers.

In all but a few cases the samples, as received, were ground in a Wiley mill to pass through a 1-mm. sieve. The fleshy fruits, because of their perishable nature, were collected in the vicinity of the Beltsville Research Center and were dried as indicated in table 1 before grinding. The methods of the Association of Official Agricultural Chemists (*1*) were followed in the determination of moisture, crude protein, true protein, crude fiber, ether extract, total ash, calcium, and phosphorus.

ANALYTICAL RESULTS

The results of the chemical analyses were calculated to the moisture-free basis to make them comparable and are recorded in table 2. The moisture content of the samples at the time the analyses were made is also given in this table.

TABLE 1.—*Sample number, name, source, time of collection, and part analyzed of the products examined*

LEGUME SEEDS

Sample No.	Common name	Scientific name [1]	Source	Time of collection	Part analyzed [2]
	Pulse family:	Leguminosae:			
1	Bean, trailing wild	*Strophostyles helvola* (L.) Britton	Chapel Hill, N. C.	Fall 1939	Seed without pod.
2	do	do	do	do	Sample 1 germinated.
3	do	do	Mayes County, Okla.	1937	Seed without pod.
4	do	*Strophostyles* sp.	Fredericksburg, Va.	August 1939	Do.
5	Beggarweed, Florida	*Desmodium tortuosum* (Sw.) DC.	Open market		Seed without hull.
6	Butterfly-pea	*Centrosema virginianum* (L.) Benth.	Fredericksburg, Va.	October 1939	Seed without pod.
7	Clover, crimson	*Trifolium incarnatum* L.	do		Seed without hull.
8	Clover, hop	*Trifolium agrarium* L.	Spartanburg, S. C.	April 1940	Do.
9	Clover, rabbitfoot	*Trifolium arvense* L.	Beltsville, Md.	July 1939	Seed with hull.
10	Clover, tick	*Desmodium bracteosum* (Michx.) DC.	Harrisburg, Ill.	Fall 1939	Do.
11	Lespedeza	*Lespedeza cyrtobotrya* Miq.	Chatham, Va.	November 1939	Seed without hull.
12	do	*Lespedeza juncea* Pers.	Thorsby, Ala.		Do.
13	do	*Lespedeza virginica* (L.) Britton	Beltsville, Md.	November 1939	Seed with hull.
14	Lespedeza, common	*Lespedeza striata* (Thunb.) H. and A. var. Kobe	Alabama		Do.
15	Lespedeza, Korean	*Lespedeza stipulacea* Maxim.	Open market		Seed without hull.
16	do	do	Alabama		Do.
17	do	do	do		Sample 16 germinated.
18	Lespedeza, sericea	*Lespedeza cuneata* G. Don	Open market		Seed without hull.
19	do	do	Beltsville, Md.	September 1939	Do.
20	do	do	do	do	Seed with hull.
21	Lespedeza, shrub	*Lespedeza bicolor* Turcz.	Chatham, Va.	November 1939	Seed without hull.
22	Locust, black	*Robinia pseudoacacia* L.	Frederick, Md.	September 1939	Seed without pod.
23	do	do	Zanesville, Ohio	Fall 1939	Do.
24	do	do	do	do	Sample 23 germinated.
25	Partridgepea	*Cassia chamaecrista* L.	Richmond, Va.	March 1939	Seed without pod.
26	do	do	Mayes County, Okla.	1937	Do.
27	do	*Cassia* sp.	Illinois	Fall 1939	Do.
28	Plant, wild sensitive	*Cassia nictitans* L.	Thorsby, Ala.		Do.
29	Sweetclover, white	*Melilotus alba* Desr.	Open market		Seed without hull.
30	Trefoil, birdsfoot	*Lotus corniculatus* L.	do		Do.
31	Vetch, common	*Vicia angustifolia* L.	do		Do.

See footnotes at end of table.

TABLE 1.—*Sample number, name, source, time of collection, and part analyzed of the products examined*—Continued

GRASS SEEDS

Sample No.	Common name	Scientific name [1]	Source	Time of collection	Part analyzed [2]
	Grass family:				
	Miscellaneous grasses:	Gramineae:			
32	Crabgrass	*Digitaria sanguinalis* (L.) Scop	Decatur, Ala	October 1939	Seed with hull.
33	do	do	Elsberry, Mo		Do.
34	Foxtail grass	*Setaria lutescens* (Weigel) F. T. Hubb	Fredericksburg, Va	August 1939	Do.
35	Redtop	*Agrostis alba* L	Open market		Do.
36	Ryegrass	*Lolium sp*	do		Do.
	Panic grasses:				
37	Fall panic grass	*Panicum dichotomiflorum* Michx	Cache, Okla	September–October 1939	Do.
38	Panic grass	*Panicum agrostoides* Spreng	Decatur, Ala	October 1939	Do.
39	do	*Panicum anceps* Michx	Forest City, Ark	October–November 1939	Do.
40	do	*Panicum fasciculatum* Swartz	Texas		Do.
41	do	*Panicum texanum* Buckl	do		Do.
42	Witchgrass	*Panicum capillare* L	Hamburg, La	Fall 1939	Do.
43	Switchgrass	*Panicum virgatum* L	San Antonio, Tex		Do.
	Paspalum grasses:				
44	Bull grass	*Paspalum boscianum* Flügge	Thomasville, Ga	September–October 1939	Do.
45	Dallis grass	*Paspalum dilatatum* Poir	Shreveport, La	October 1939	Do.
46	Paspalum grass	*Paspalum floridanum* Michx	Hattiesburg, Miss	Fall 1939	Do.
47	do	*Paspalum laeve* Michx	Fredericksburg, Va	September 1939	Do.

MISCELLANEOUS SEEDS

	Buckwheat family:	Polygonaceae:			
48	Sorrel, sheep	*Rumex acetosella* L	Beltsville, Md	June 1940	Seed with hull.
49	Smartweed	*Polygonum setaceum* Baldw	Decatur, Ala	October 1939	Do.
50	do	*Polygonum* sp	Greenbelt, Md	December 1939	Seed without hull.
	Composite family:	Compositae:			
51	Ragweed	*Ambrosia aptera* DC	Texas		Seed.
52	do	*Ambrosia artemisiifolia* L	Ithaca, N. Y		Do.
53	Madder family: Buttonweed, narrow-leaved.	Rubiaceae: *Diodia teres* Walt	Open market		Do.
54	Touch-me-not family: Jewelweed	Balsaminaceae: *Impatiens pallida* Nutt	Beverly, W. Va	September–October 1939	Do.

	Beech family:	Fagaceae:			
55	Oak, bear	*Quercus ilicifolia* Wang	Wrightstown, N. J	Fall 1939	Acorn without cup.
56	Oak, blackjack	*Quercus marilandica* Muench	Hattiesburg, Miss	do	Do.
57	do	do	do	do	Do.
58	do	do	Springfield, Mo	do	Do.
59	Oak, bluejack	*Quercus cinerea* Michx	Hattiesburg, Miss	do	Do.
60	Oak, chestnut	*Quercus prinus* L	Arlington, Va	September 1939	Do.
61	do	do	Elk Range, Va	Fall 1939	Do.
62	Oak, Havard's	*Quercus havardi* Rydb	Beckham County, Okla	do	Do.
63	Oak, live	*Quercus virginiana* Mill	Hattiesburg, Miss	do	Do.
64	Oak, Nuttall's	*Quercus nuttallii* Palmer	St. Charles, Ark	do	Do.
65	Oak, pin	*Quercus palustris* Muench	Harrisburg, Ill	do	Do.
66	Oak, post	*Quercus stellata* Wang	Blacksburg, Va	do	Do.
67	do	do	Cache, Okla	September–October 1939	Do.
68	Oak, Spanish	*Quercus falcata* Michx	Hattiesburg, Miss	Fall 1939	Do.
69	Oak, water	*Quercus nigra* L	Decatur, Ala	October 1939	Do.
70	do	do	St. Charles, Ark	Fall 1939	Do.
71	do	do	Hattiesburg, Miss	do	Do.
72	do	do	do	do	Sample 71 germinated.
73	Oak, white	*Quercus alba* L	Elk Range, Va	Fall 1939	Acorn without cup.
74	Oak, willow	*Quercus phellos* L	Decatur, Ala	October 1939	Do.
75	do	do	Fredericksburg, Va	September 1939	Do.
76	do	do	Monticello, Ark	November 1939	Do.
77	do	do	St. Charles, Ark	Fall 1939	Do.
78	do	do	do	do	Sample 77, shell only.[3]
79	do	do	do	do	Sample 77, kernel only.[4]
80	Birch family: Hazelnut	Betulaceae: *Corylus* sp			Nut without involucre.
	Pine family:	Pinaceae:			
81	Pine loblolly	*Pinus taeda* L	Open market		Seed without wing.
82	Pine, longleaf	*Pinus palustris* Mill	Hattiesburg, Miss	October 1939	Do.
83	Pine, ponderosa	*Pinus ponderosa* Laws	Elsberry, Mo		Do.
84	Pine, shortleaf	*Pinus echinata* Mill	Springfield, Mo	Fall 1939	Do.
85	Witch-hazel family: Sweetgum	Hamamelidaceae: *Liquidambar styraciflua* L	Tennessee	1937	Do.

See footnotes at end of table.

TABLE 1.—*Sample number, name, source, time of collection, and part analyzed of the products examined*—Continued

FRUITS

Sample No.	Common name	Scientific name [1]	Source	Time of collection	Part analyzed [2]
86	Barberry family: Barberry, Japanese	Berberidaceae: *Berberis thunbergii* DC	Beltsville, Md	April 1940	Whole fruit.
87	Buckthorn family: Plum, hog	Rhamnaceae: *Colubrina texensis* Gray	San Antonio, Tex		Do.
	Cashew family:	Anacardiaceae:			
88	Skunkbush	*Rhus canadensis* var. *trilobata* (Nutt.) Gray.	Sayre, Okla	Fall 1939	Seed without pulp.
89	Sumac, dwarf	*Rhus copallina* L	Hattiesburg, Miss	do	Whole fruit.
90	do	do	Decatur, Ala	October 1939	Pulp without seed.
91	do	do	Lancaster, Pa	November 1939	Seed without pulp.
92	Sumac, smooth	*Rhus glabra* L	Fredericksburg, Va	September 1939	Whole fruit.
93	do	do	Wenatchee, Wash	Fall 1939	Do.
94	do	do	Washtenaw County, Mich.	November–December 1940.	Do.
95	do	do	Okanogan, Wash	October 1939	Pulp without seed.
96	Sumac, staghorn	*Rhus typhina* L	Lancaster, Pa	November 1939	Seed without pulp.
	Ebony family:	Ebenaceae:			
97	Persimmon, common	*Diospyros virginiana* L	Beltsville, Md	January 1940	Pulp without seed [5]
98	do	do	do	do	Seed without pulp.[5]
	Honeysuckle family:	Caprifoliaceae:			
99	Coralberry	*Symphoricarpos orbiculatus* Moench	Greenbelt, Md	December 1939	Whole fruit.[6]
100	Honeysuckle	*Lonicera morrowii* Gray	Beltsville, Md	June 1940	Do.[5]
101	Honeysuckle, Japanese	*Lonicera japonica* Thunb	Berwyn, Md	November 1939	Do.[6]
102	Lily family: Saw brier	Liliaceae: *Smilax glauca* Walt	Greenbelt, Md	December 1939	Do.[6]
	Nettle family:	Urticaceae:			
103	Hackberry	*Celtis pallida* Torr	San Antonio, Tex		Do.
104	Mulberry	*Morus alba* L	Beltsville, Md	June 1940	Do.[5]
105	do	*Morus* sp	Virginia	June 1939	Do.[5]
106	Oleaster family: Russian-olive	Elaeagnaceae: *Elaeagnus angustifolia* L	Albuquerque, N. Mex	November 1938	Do.
107	Olive family: Privet	Oleaceae: *Ligustrum obtusifolium* var. *regelianum* (Koehne) Rehd.	Beltsville, Md	April 1940	Do.
	Rose family:	Rosaceae:			
108	Cherry, wild black	*Prunus serotina* Ehrh	Fredericksburg, Va	September 1939	Fruit with stone.[6]
109	Dewberry, wild	*Rubus* sp	Beltsville, Md	July 1940	Whole fruit.[5]
110	Plum, beach	*Prunus maritima* Marsh	Sandy Hook, N. J	September 1939	Stones, cleaned.[5]
111	Rose, Japanese	*Rosa multiflora* Thunb	Open market		Whole fruit.
112	Rose, rambling	*Rosa rugosa* Thunb	Beltsville, Md	March 1940	Do.
113	Rose, swamp	*Rosa palustris* Marsh	Blacksburg, Va	November 1939	Do.
114	do	do	do	April 1940	Do.
115	Strawberry, wild	*Fragaria* sp	Greenbelt, Md	June 1940	Fruit with calyx.[5]

116	Sweetgale family: Bayberry	Myricaceae: *Myrica pensylvanica* Lois	Wrightstown, N. J.	Fall 1939	Whole fruit.
117	Waxmyrtle	*Myrica cerifera* L.	Thorsby, Ala.		Do.
118	....do	....do	Virginia Beach, Va.	Fall 1939	Do.
119	Vine family: Grape, Frost	Vitaceae: *Vitis vulpina* L.	Washtenaw County, Mich.	October–November 1940	Do.[6]
		TUBERS			
120	Sedge family: Chufa	Cyperaceae: *Cyperus esculentus* L.	Open market		Tubers.

[1] Authority for nomenclature is the Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.
[2] Unless otherwise indicated the part analyzed was air-dried.
[3] 30.08 percent of whole acorn.
[4] 69.92 percent of whole acorn.
[5] Dried at 100° C.
[6] Dried at room temperature.

TABLE 2.—*Percentage analyses of the products examined*

LEGUME SEEDS

Sample No.	Common name	Moisture content when analyzed	Proximate chemical composition on moisture-free basis								
			Crude protein [1]	True protein [2]	Nonprotein nitrogen compounds [3]	Crude fiber	Nitrogen-free extract	Fat, or ether extract	Ash	Calcium	Phosphorus
	Pulse family:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	Bean, trailing wild	9.08	32.92	31.08	1.39	10.98	51.92	0.58	4.05	0.10	0.60
2	....do	6.81	33.16	29.68	2.62	11.21	51.54	.60	4.35	----	----
3	....do	10.43	31.75	28.89	2.15	11.50	52.50	.64	4.32	.13	.60
4	....do	9.39	32.81	30.33	1.87	13.12	49.16	.81	4.71	.14	.54
5	Beggarweed, Florida	8.47	36.55	32.16	3.30	13.71	37.80	9.52	3.51	.15	.67
6	Butterfly-pea	9.44	26.48	21.71	3.59	10.44	58.50	2.78	2.98	.24	.38
7	Clover, crimson	7.46	41.65	36.05	4.21	11.43	42.19	1.86	4.26	.13	.79
8	Clover, hop	7.08	42.19	33.87	6.25	9.13	37.10	10.20	3.45	.08	.69
9	Clover, rabbitfoot	7.16	20.69	19.30	1.04	26.12	46.39	2.77	4.38	1.23	.37
10	Clover, tick	6.11	22.41	18.13	3.22	28.85	34.84	5.24	9.72	.76	.44
11	Lespedeza	7.22	35.59	31.85	2.81	12.60	35.44	12.33	4.97	.17	.59
12	....do	8.67	42.72	39.35	2.53	11.17	36.89	6.64	3.42	.14	.49
13	....do	7.58	33.19	29.12	3.06	16.71	42.01	4.54	4.56	.61	.54
14	Lespedeza, common	7.66	43.94	40.91	2.29	12.03	33.20	6.95	4.62	.29	.83
15	Lespedeza, Korean	9.02	43.60	41.41	1.65	9.80	33.10	8.75	5.29	.40	.82
16	....do	7.16	40.73	38.84	1.42	11.02	35.74	8.38	4.60	.38	.87
17	....do	5.68	43.72	35.54	6.16	11.79	32.97	8.25	5.29	----	----
18	Lespedeza, sericea	8.73	38.02	34.16	2.90	13.88	41.39	4.02	3.65	.14	.50
19	....do	7.05	38.36	34.39	2.98	13.33	40.13	4.96	4.21	.15	.59
20	....do	7.23	32.34	29.27	2.31	16.71	42.72	4.65	4.34	.58	.50
21	Lespedeza, shrub	7.75	38.44	35.60	2.14	13.07	33.97	11.11	4.11	.17	.54
22	Locust, black	7.42	46.65	34.96	8.79	16.33	23.64	11.97	4.31	.25	.90
23	....do	6.33	46.83	35.85	8.26	15.60	25.15	10.46	4.68	.23	.79
24	....do	5.40	50.34	35.32	11.30	17.05	21.29	10.44	4.60	----	----
25	Partridgepea	9.21	36.16	33.74	1.82	7.99	45.49	6.63	4.33	.59	.46
26	....do	8.92	39.89	35.89	3.01	8.65	42.84	5.39	4.22	.63	.49
27	....do	8.11	40.06	35.54	3.40	8.81	45.00	3.40	3.85	.62	.54
28	Plant, wild sensitive	10.24	40.92	35.46	4.10	7.68	45.03	3.03	4.70	.51	.55
29	Sweetclover, white	7.82	40.56	36.32	3.19	12.30	39.79	4.52	3.88	.30	.59
30	Trefoil, birdsfoot	8.54	37.92	32.52	4.06	14.13	39.69	5.39	4.21	.32	.56
31	Vetch, common	8.73	34.71	29.89	3.63	7.11	55.20	.48	3.69	.20	.54

	GRASS SEEDS										
	Grass family:										
	Miscellaneous grasses:										
32	Crabgrass	12.08	13.55	12.73	0.61	15.45	61.59	3.30	6.32	0.13	0.36
33	....do	9.29	12.82	12.34	.36	14.85	63.53	3.62	5.30	.12	.41
34	Foxtail grass	7.16	14.28	13.91	.28	67.57	8.63	.42	9.19	.10	.25
35	Redtop	6.83	20.26	19.52	.56	10.34	55.57	7.03	6.98	.31	.58
36	Ryegrass	8.86	8.99	8.38	.45	10.56	74.20	2.05	4.36	.23	.35
	Panic grasses:										
37	Fall panic grass	7.68	15.21	13.96	.93	19.89	51.70	4.13	9.39	.13	.34
38	Panic grass	11.36	12.94	12.44	.37	23.23	54.02	.88	9.06	.20	.33
39	....do	5.65	11.79	11.56	.17	29.05	51.48	2.08	5.66	.16	.23
40	....do	6.96	14.37	12.76	1.21	29.58	43.49	2.98	9.98	.30	.21
41	....do	6.61	17.36	15.50	1.39	23.20	50.60	4.39	4.92	.12	.26
42	Witchgrass	9.12	12.80	12.04	.57	19.67	54.08	3.09	10.55	.34	.39
43	Switchgrass	5.72	15.00	14.26	.56	14.63	59.29	5.24	6.02	.12	.39
	Paspalum grasses:										
44	Bull grass	9.57	7.70	7.55	.11	17.95	65.75	3.82	4.82	.14	.38
45	Dallis grass	5.49	9.00	7.83	.88	33.57	44.72	5.02	7.98	.15	.37
46	Paspalum grass	8.98	9.16	8.64	.40	28.44	55.99	1.81	4.72	.09	.14
47	....do	6.69	6.19	5.32	.66	43.28	44.83	1.03	4.88	.08	.13
	MISCELLANEOUS SEEDS										
	Buckwheat family:										
48	Sorrel, sheep	10.71	8.20	7.63	0.43	18.74	62.97	3.29	6.94	0.29	0.26
49	Smartweed	6.80	11.72	10.23	1.13	23.74	58.44	1.80	4.66	.48	.38
50	....do	9.21	10.78	10.28	.39	18.37	65.12	3.84	2.00	.11	.29
	Composite family:										
51	Ragweed	3.83	21.11	19.54	1.19	27.57	24.57	22.10	5.03	.71	.58
52	....do	7.08	24.50	23.54	.73	34.10	24.53	13.47	3.63	.36	.56
53	Madder family: Buttonweed, narrow-leaved	5.55	12.45	11.29	.88	44.90	28.29	3.65	10.99	.61	.19
54	Touch-me-not family: Jewelweed	6.01	28.23	27.75	.36	2.95	19.59	44.55	4.80	.47	.97
	MAST										
	Beech family:										
55	Oak, bear	9.62	6.10	5.94	0.12	18.27	54.61	19.41	1.65	0.19	0.10
56	Oak, blackjack	14.65	6.29	6.28	.01	20.94	60.11	10.66	2.00	.37	.09
57	....do	7.77	5.48	5.07	.30	21.79	52.63	18.18	2.03	.40	.11
58	....do	8.21	5.75	5.49	.20	21.79	53.03	17.73	1.76	.36	.09
59	Oak, bluejack	15.71	5.92	5.92	.00	12.52	67.06	12.66	1.84	.33	.09
60	Oak, chestnut	6.89	6.42	6.06	.28	15.22	72.93	3.34	2.17	.14	.12
61	....do	7.37	3.58	3.56	.02	20.32	60.35	13.97	1.78	.13	.08

See footnotes at end of table.

TABLE 2.—*Percentage analyses of the products examined*—Continued

MAST—Continued

Sample No.	Common name	Moisture content when analyzed	Proximate chemical composition on moisture-free basis								
			Crude protein [1]	True protein [2]	Nonprotein nitrogen compounds [3]	Crude fiber	Nitrogen-free extract	Fat, or ether extract	Ash	Calcium	Phosphorus
	Beech family—Continued.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
62	Oak, Havard's	9.01	7.73	6.28	1.09	12.22	71.42	6.65	2.34	0.14	0.11
63	Oak, live	10.17	5.22	4.52	.52	16.71	67.95	8.59	1.71	.18	.08
64	Oak, Nuttall's	5.65	3.83	3.57	.19	13.24	66.65	14.99	1.36	.17	.05
65	Oak, pin	8.81	7.16	6.37	.59	15.58	58.37	17.82	1.27	.13	.08
66	Oak, post	7.70	5.15	4.89	.20	19.46	66.74	5.74	2.97	.40	.11
67	....do	8.24	4.83	4.59	.19	19.61	65.23	7.60	2.78	.38	.10
68	Oak, Spanish	10.64	4.20	4.16	.02	20.60	57.73	15.57	1.92	.43	.08
69	Oak, water	7.11	4.27	4.20	.05	17.60	54.17	22.83	1.15	.29	.08
70	....do	7.66	3.97	3.89	.06	18.87	54.16	21.79	1.23	.21	.06
71	....do	7.53	3.67	3.64	.02	18.99	54.82	20.86	1.67	.30	.04
72	....do	5.10	4.59	4.50	.07	19.60	50.49	23.73	1.61		
73	Oak, white	9.67	6.73	5.85	.66	17.38	67.25	5.67	3.19	.19	.14
74	Oak, willow	11.10	4.24	4.08	.12	19.36	54.74	19.61	2.09	.30	.02
75	....do	13.37	5.08	5.06	.02	18.82	55.87	18.52	1.71	.30	.07
76	....do	9.32	4.61	4.34	.20	18.28	52.84	22.99	1.35	.28	.08
77	....do	11.33	4.93	4.92	.01	18.63	52.79	21.86	1.79	.29	.08
78	....do	7.55	2.47	2.41	.04	54.57	41.07	0.51	1.40	.69	.02
79	....do	5.63	5.81	5.80	.01	2.51	60.42	29.52	1.74	.10	.12
80	Birch family: Hazelnut	5.97	6.72	6.61	.09	51.98	19.32	20.53	1.47	.33	.10
	Pine family:										
81	Pine, loblolly	7.36	15.88	15.63	.18	56.45	16.98	6.74	4.02	.04	.35
82	Pine, longleaf	6.88	33.85	33.17	.50	23.93	8.59	28.87	4.94	.08	.73
83	Pine, ponderosa	7.13	21.28	21.10	.13	37.77	14.22	21.97	4.81	.06	.61
84	Pine, shortleaf	7.41	28.63	28.10	.40	32.95	9.88	22.10	6.57	.08	.76
85	Witch-hazel family: Sweetgum	4.91	26.01	25.32	.52	17.95	33.62	13.86	8.73	1.22	.57
	FRUITS										
86	Barberry family: Barberry, Japanese	12.54	15.25	12.81	1.84	10.78	62.32	8.24	4.01	0.33	0.33
87	Buckthorn family: Plum, hog	4.05	19.25	17.94	.99	31.21	30.40	17.42	2.04	.34	.22
	Cashew family:										
88	Skunkbush	5.71	15.81	14.19	1.22	25.97	43.94	12.81	1.87	.08	.31
89	Sumac, dwarf	5.65	8.21	7.80	.31	28.54	42.88	17.17	3.30	.16	.16
90	....do	5.47	4.88	4.68	.15	20.66	57.65	10.83	6.03	.85	.10

91	....do	7.06	13.37	12.74	.47	29.74	41.92	12.91	2.22	.14	.37
92	Sumac, smooth	8.63	5.28	5.10	.13	35.11	46.41	10.05	3.20	.47	.23
93	....do	4.59	4.97	4.94	.02	31.61	46.58	13.53	3.32	.41	.25
94	....do	5.33	5.22	4.90	.24	28.78	45.83	17.21	3.04	.48	.24
95	....do	6.17	3.02	2.78	.18	21.91	50.03	15.59	9.51	.94	.10
96	Sumac, staghorn	4.88	10.75	10.18	.43	28.64	46.27	11.94	2.54	.18	.48
	Ebony family:										
97	Persimmon, common	4.51	3.27	2.87	.30	5.29	87.44	.89	3.21	.12	.08
98	....do	5.89	9.57	8.68	.67	23.61	63.00	2.02	2.02	.13	.20
	Honeysuckle family:										
99	Coralberry	6.98	8.50	7.72	.59	21.40	59.78	6.27	4.24	.40	.22
100	Honeysuckle	3.50	7.97	7.17	.60	9.09	75.44	3.89	3.81	.31	.24
101	Honeysuckle, Japanese	10.56	10.42	8.81	1.21	6.65	69.37	7.86	6.10	.66	.31
102	Lily family: Saw brier	7.58	10.24	8.12	1.59	18.59	60.77	7.53	3.40	.25	.16
	Nettle family:										
103	Hackberry	4.47	8.23	7.42	.61	8.95	45.81	4.75	32.46	14.56	.19
104	Mulberry	3.08	8.96	7.91	.78	9.98	67.86	8.07	5.40	.67	.33
105	....do	3.10	5.46	3.99	1.10	5.02	80.04	2.56	7.29	.60	.20
106	Oleaster family: Russian-olive	9.91	9.45	7.54	1.43	20.29	64.08	4.53	2.13	.22	.04
107	Olive family: Privet	11.66	12.76	12.04	.53	13.70	56.25	13.38	4.10	.36	.29
	Rose family:										
108	Cherry, wild black	6.71	13.94	12.88	.79	32.66	43.00	6.97	3.70	.42	.20
109	Dewberry, wild	3.47	5.79	5.47	.24	21.50	64.39	4.89	3.51	.33	.19
110	Plum, beach	5.50	6.50	6.14	.28	57.93	23.55	11.26	.84	.15	.11
111	Rose, Japanese	5.56	10.04	9.49	.41	23.14	56.56	6.07	4.33	.90	.33
112	Rose, rambling	9.46	10.98	9.94	.78	40.09	40.11	6.19	2.89	.86	.19
113	Rose, swamp	5.74	10.76	9.90	.65	30.87	47.06	7.02	4.50	.89	.20
114	....do	6.20	10.16	9.69	.35	31.97	45.94	7.47	4.58	.95	.26
115	Strawberry, wild	2.46	7.59	7.13	.35	20.54	58.25	6.93	6.80	.65	.29
	Sweetgale family:										
116	Bayberry	6.19	7.08	7.02	.04	41.52	24.88	24.78	1.78	.13	.03
117	Waxmyrtle	6.80	5.56	5.47	.06	42.10	29.04	21.81	1.52	.26	.04
118	....do	7.38	5.88	5.74	.11	40.30	21.23	31.00	1.62	.11	.11
119	Vine family: Grape, Frost	7.90	9.82	8.51	.98	22.21	54.36	9.52	4.42	.52	.26
	TUBERS										
120	Sedge family: Chufa	9.86	4.96	2.60	1.78	8.96	55.41	29.54	1.71	.03	.61

[1] 6.25 × total nitrogen.
[2] 6.25 × albuminoid nitrogen.
[3] 4.7 × difference between total and albuminoid nitrogen.

The ranges in composition of the groups into which the samples were classified are shown in table 3. Several of the feedstuffs whose composition was not representative of their groups were omitted from the table. Since wide ranges were found even within the same botanical family groups, it was in many instances difficult to classify the wild feedstuffs into groups having distinctly definite characteristics.

TABLE 3.—*Ranges of composition of the groups*

Group name	Moisture content when analyzed	Range of chemical composition on moisture-free basis								
		Crude protein [1]	True protein [2]	Nonprotein nitrogen compounds [3]	Crude fiber	Nitrogen-free extract	Fat, or ether extract	Ash	Calcium	Phosphorous
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Legumes (seed)	5–10	21–50	18–41	1–11	7–29	21–58	0. 5–12	3–10	0. 1–1. 2	0. 4–0. 9
Grasses (seed) [4]	6–12	6–20	5–20	. 1–1. 4	10–43	43–74	. 9– 7	4–10	. 1– . 3	. 1– . 6
Miscellaneous (seed) [5]	4–11	8–24	8–24	. 4–1. 2	18–34	25–65	1. 8–22	2– 7	. 1– . 7	. 2– . 6
Mast (seed) [6]	6– 7	16–34	16–33	. 1– . 5	24–56	9–17	7–29	4– 7	. 0– . 1	. 4– . 8
Mast (nuts) [7]	5–16	4– 8	4– 6	0–1. 1	12–22	50–73	3–24	1– 3	. 1– . 4	0– . 1
Fruits [8]	3–13	3–19	3–18	0–1. 8	5–42	21–87	. 9–31	2– 9	. 1–1. 0	0– . 5
Tubers	10	5	3	2	9	55	30	2	0. 03	. 6

[1] 6.25×total nitrogen.
[2] 6.25×albuminoid nitrogen.
[3] 4.7×difference between total and albuminoid nitrogen.
[4] Excluding foxtail grass (sample 34).
[5] Excluding buttonweed (sample 53) and jewelweed (sample 54).
[6] Excluding sweetgum (sample 85).
[7] Excluding willow oak (shell only and kernel only (samples 78 and 79), and hazelnut (sample 80).
[8] Excluding hackberry (sample 103) and beach plum (sample 110).

The legume seeds had a high crude protein content, but in many cases a considerable portion of the nitrogen was in the form of nonprotein nitrogen compounds. They also contained considerable nitrogen-free extract (carbohydrates), moderate quantities of fat and crude fiber, and more calcium and phosphorus than the domestic cereal grains.

The grass seeds in general were comparable to wheat and corn but contained slightly more protein, considerably more crude fiber, and less nitrogen-free extract. Foxtail grass seed was a marked exception in this group, since it had a very high content of crude fiber and a very low content of nitrogen-free extract.

Among the miscellaneous seeds a considerable range in composition was found, but this was to be expected since four families were represented. Jewelweed seeds were notably high in fat, protein, and phosphorus, but contained little crude fiber.

The mast group may conveniently be divided into seeds and nuts. The seeds were high in protein and crude fiber and low in nitrogen-free extract, whereas the nuts were low in protein and phosphorus and high in nitrogen-free extract. The quantity of fat found in both seeds and nuts varied considerably. Hazelnuts were very high in crude fiber, probably because of their thick shell, and low in nitrogen-free extract. Sweetgum seeds contained much more calcium than the other mast samples. One sample of acorns was separated into shell (sample 78) and kernel (sample 79) and the two parts were analyzed separately. The results indicate that the nutritive value

of the acorn depends on whether the shell is included in the diet of the animal.

The fruits varied greatly in composition. This group was characterized in the main by a high content of nitrogen-free extract. The fruit of the sweetgale family, however, had only a moderate content of nitrogen-free extract and a rather high content of crude fiber and fat. Separate analyses of the seed (samples 91 and 96) and pulp (samples 90 and 95) of the sumac fruit indicate that the seed contains more protein and phosphorus but much less ash and calcium than the pulp. The fruit of the sumac probably has little nutritive value since Errington (*4*) found that it failed to maintain the live weight of captive bobwhite quail when fed as the sole source of feed. This observation was confirmed by Nestler and Bailey,[4] who showed that captive bobwhite quail under very favorable conditions of shelter and temperature lost weight when the only feedstuff supplied to them was sumac fruit, pulp, or seed. The fruit of the hackberry was unusual in that the ash and calcium content was exceptionally high.

Chufa, the only member of the tuber group analyzed, had a high content of fat and nitrogen-free extract, but contained little protein.

DISCUSSION

Certain factors that influence the chemical composition of feedstuffs should be considered. The type of soil in which a plant is grown undoubtedly has some effect on the chemical composition of the fruit and seed. This subject has been adequately treated by Browne (*3*) and many others, but Hart, Guilbert, and Goss (*6*), in discussing range forages, stated that the difference in composition between species is more marked than the variation within the species when grown on different areas. The stage of development of the plant and the conditions of exposure to the weather to which it has been subjected influence to a great extent the chemical composition of the fruit and seed. Guilbert, Mead, and Jackson (*5*) reported that seeds collected relatively late in the season may have some of their nutritive value leached out. This confirms the earlier report of Le Clerc and Breazeale (*8*), who stated that when plants dry and wilt the inorganic constituents exude to the surface, from which they may be easily washed by rain.

It is necessary to make feeding tests before attempting to arrive at definite conclusions regarding the value of wild feedstuffs in the diet of wild and domestic animals and birds. Many of these feedstuffs, such as sumac, may be found to be of doubtful value. Others may yield excellent results with some animals and poor results with others. The beneficial effect of one nutritive constituent may be overbalanced by the harmful effect of another. For example, King and Titus (*7*) found in experiments with growing chicks that acorns of the willow oak are a rich source of vitamin A, comparable with alfalfa-leaf meal, but Olsen (*10*) showed that when hens were fed diets containing 25 percent of meat or hulls of the acorns of either the white or black oak, they produced eggs having yolks of an undesirable, greenish color.

[4] Unpublished data of R. B. Nestler and W. W. Bailey, of the Patuxent Research Refuge, Bowie, Md.

SUMMARY

Chemical analyses were made of 120 samples of American wild feedstuffs. The samples included legume seeds, grass seeds, miscellaneous seeds, mast, fruits, and tubers.

Legume seeds have good nutritive value as indicated by high protein and nitrogen-free extract content. Grass seeds and fruits are of lower nutritive value and supply mainly nitrogen-free extract, although some of the fruits contain considerable fat. The seeds of the mast group are concentrated feedstuffs having, in general, a high protein and a low nitrogen-free extract content, whereas the nuts of this group have a low protein and a high nitrogen-free extract content. The quantity of fat found in both seeds and nuts varies considerably.

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